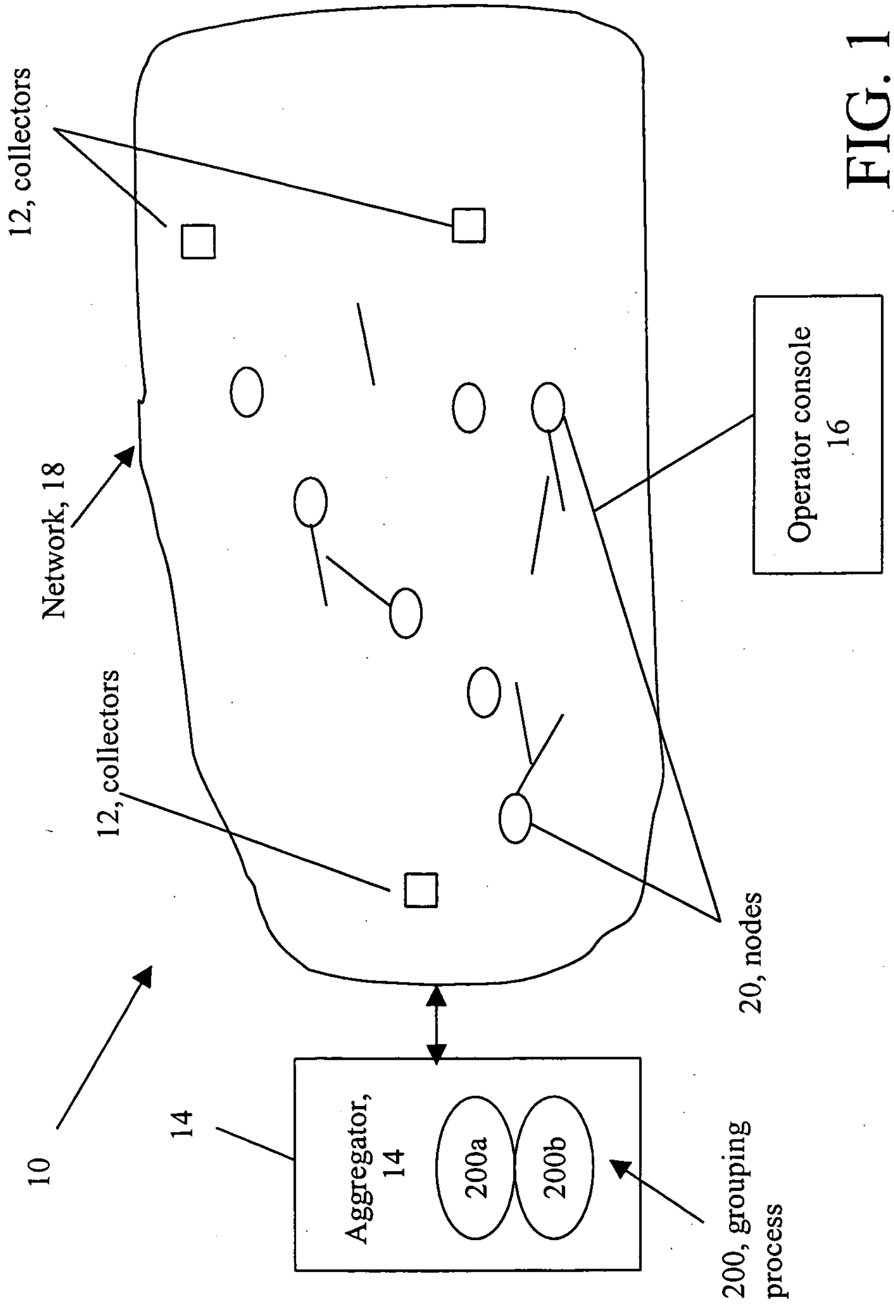

10
14
Aggregator, 14
200a
200b
200, grouping process
12, collectors
Network, 18
12, collectors
20, nodes
Operator console 16

FIG. 1

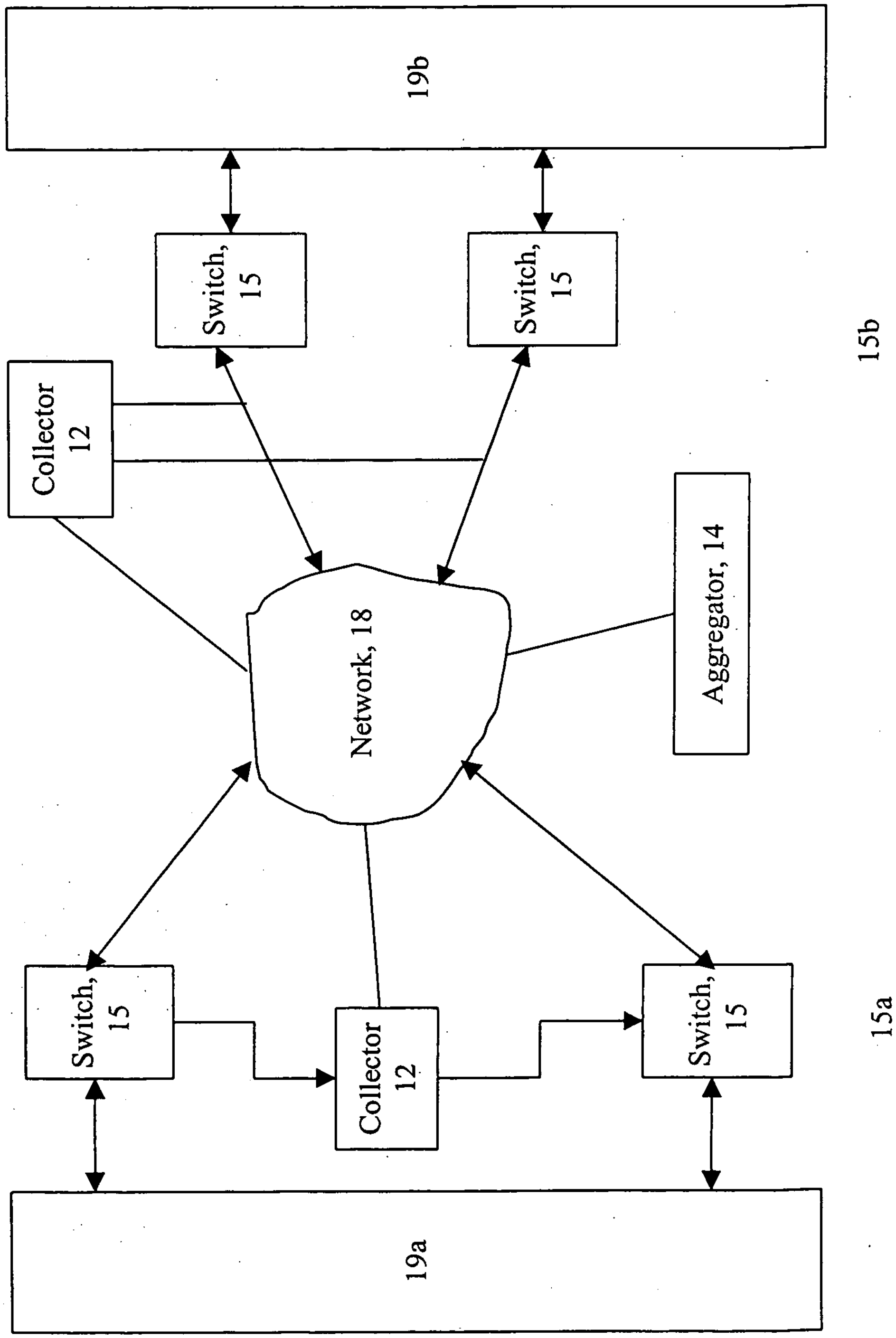

19b
Switch, 15
Switch, 15
15b
Collector 12
Network, 18
Aggregator, 14
Switch, 15
Collector 12
Switch, 15
15a
19a

FIG. 2

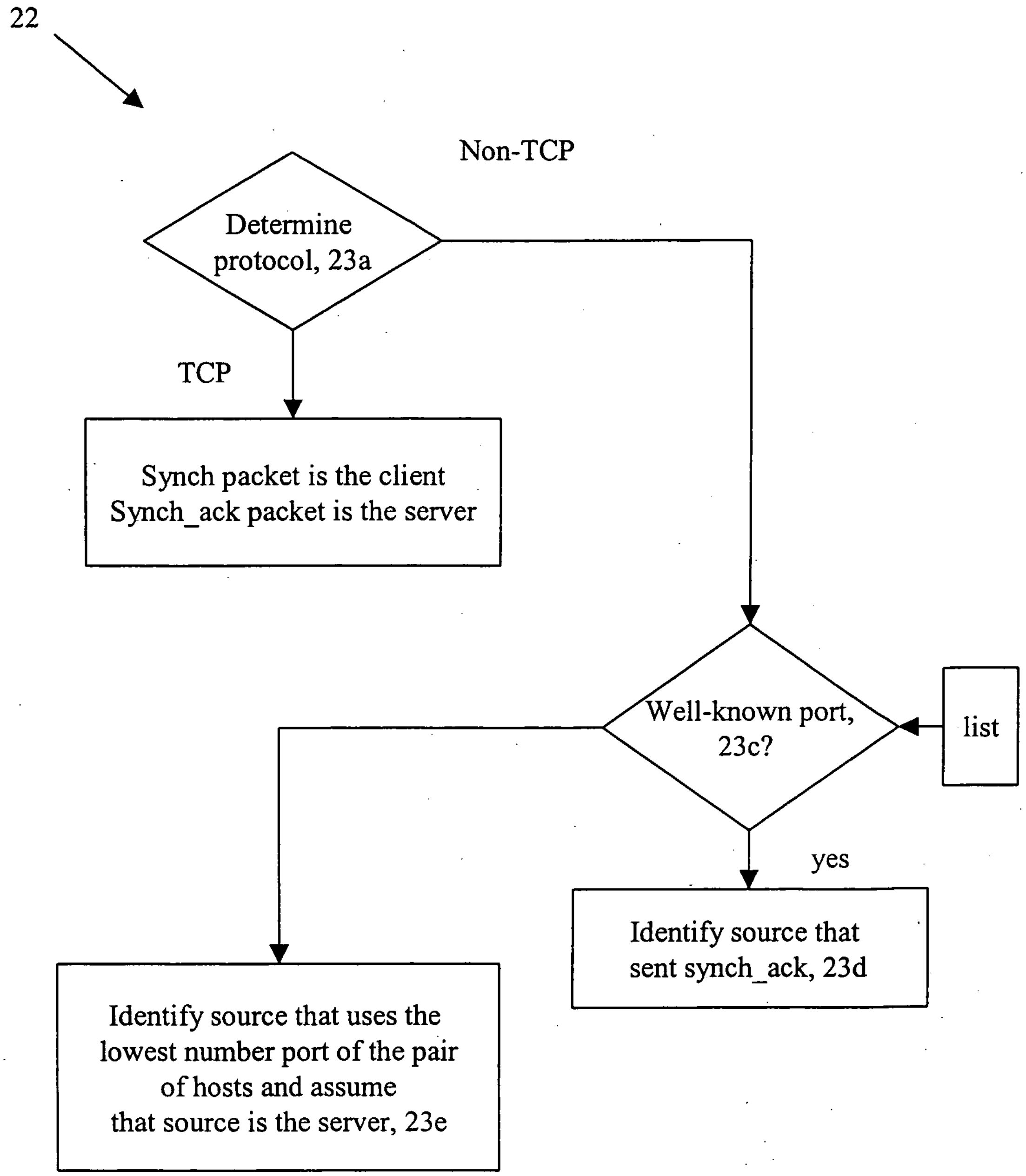

22
Non-TCP
Determine protocol, 23a
TCP
Synch packet is the client
Synch_ack packet is the server
Well-known port, 23c?
list
yes
Identify source that sent synch_ack, 23d
Identify source that uses the lowest number port of the pair of hosts and assume that source is the server, 23e

FIG. 2A

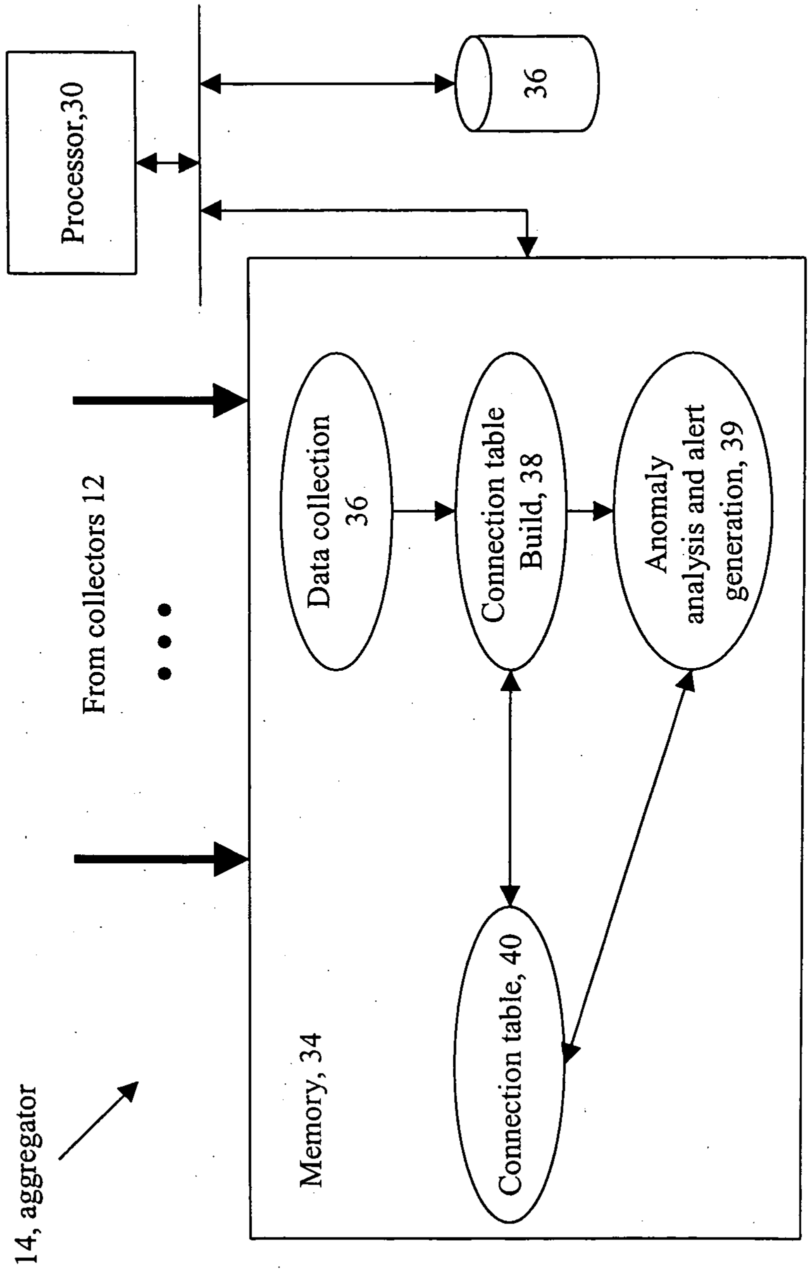

14, aggregator
From collectors 12
Processor,30
36
Memory, 34
Data collection 36
Connection table Build, 38
Anomaly analysis and alert generation, 39
Connection table, 40

FIG. 3

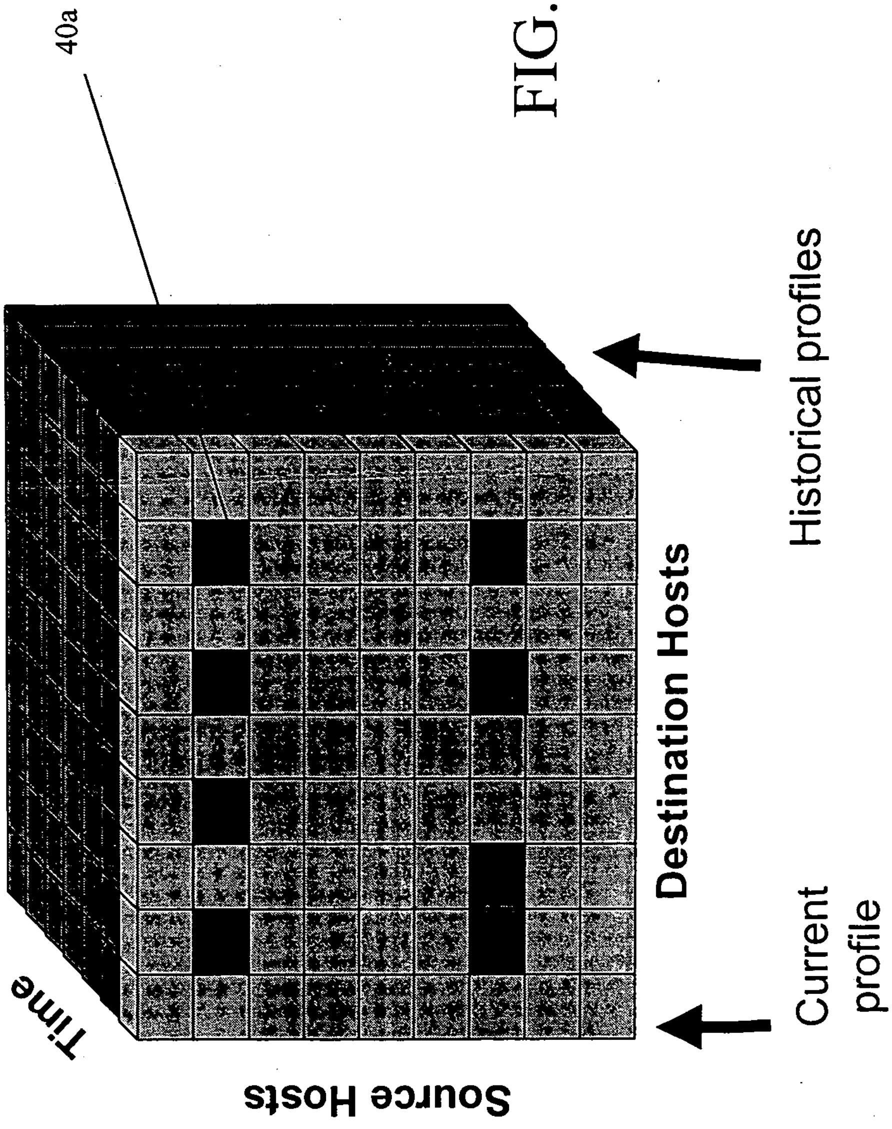

40a
Historical profiles
Destination Hosts
Current profile
Time
Source Hosts

FIG. 4

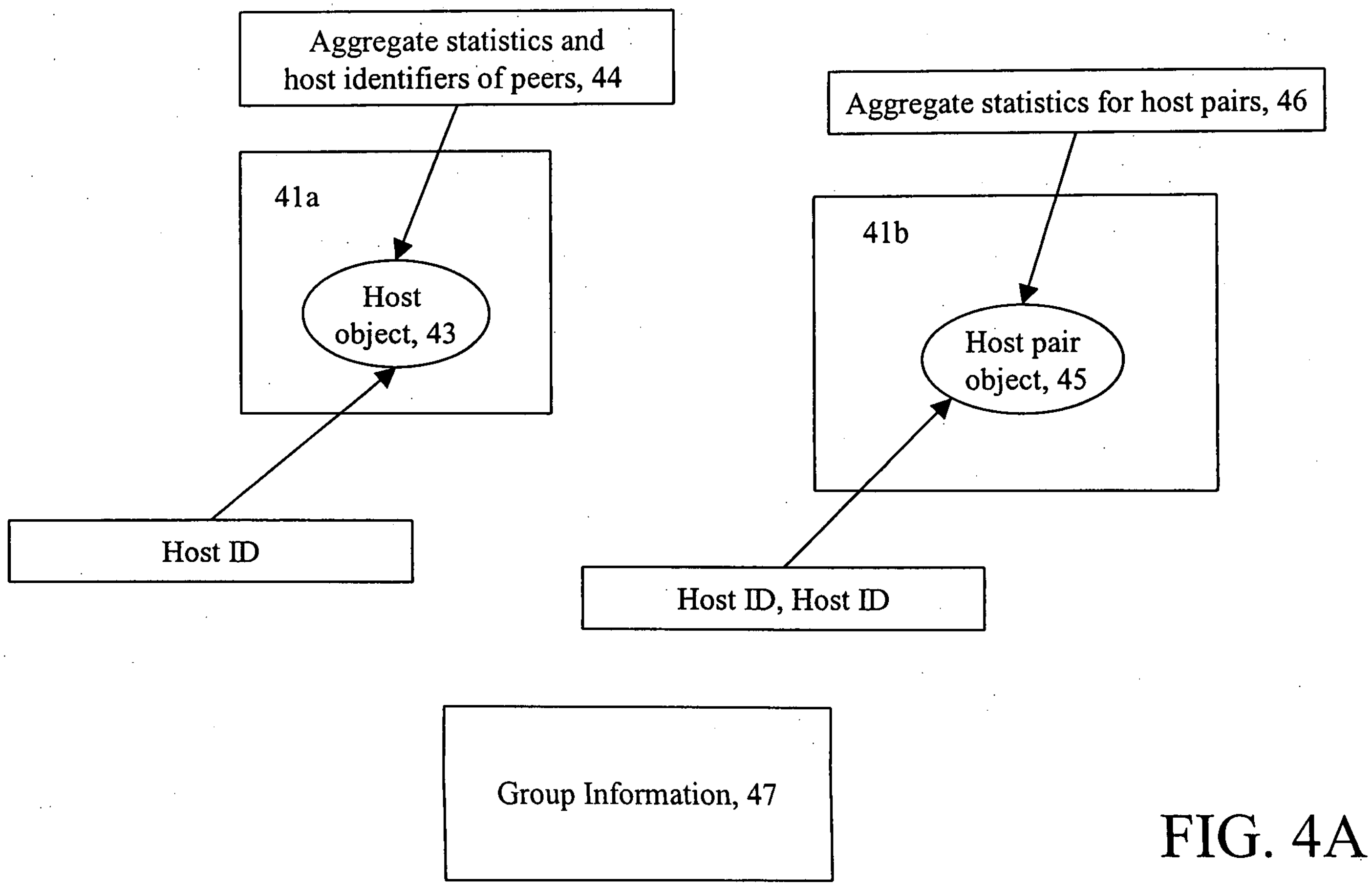
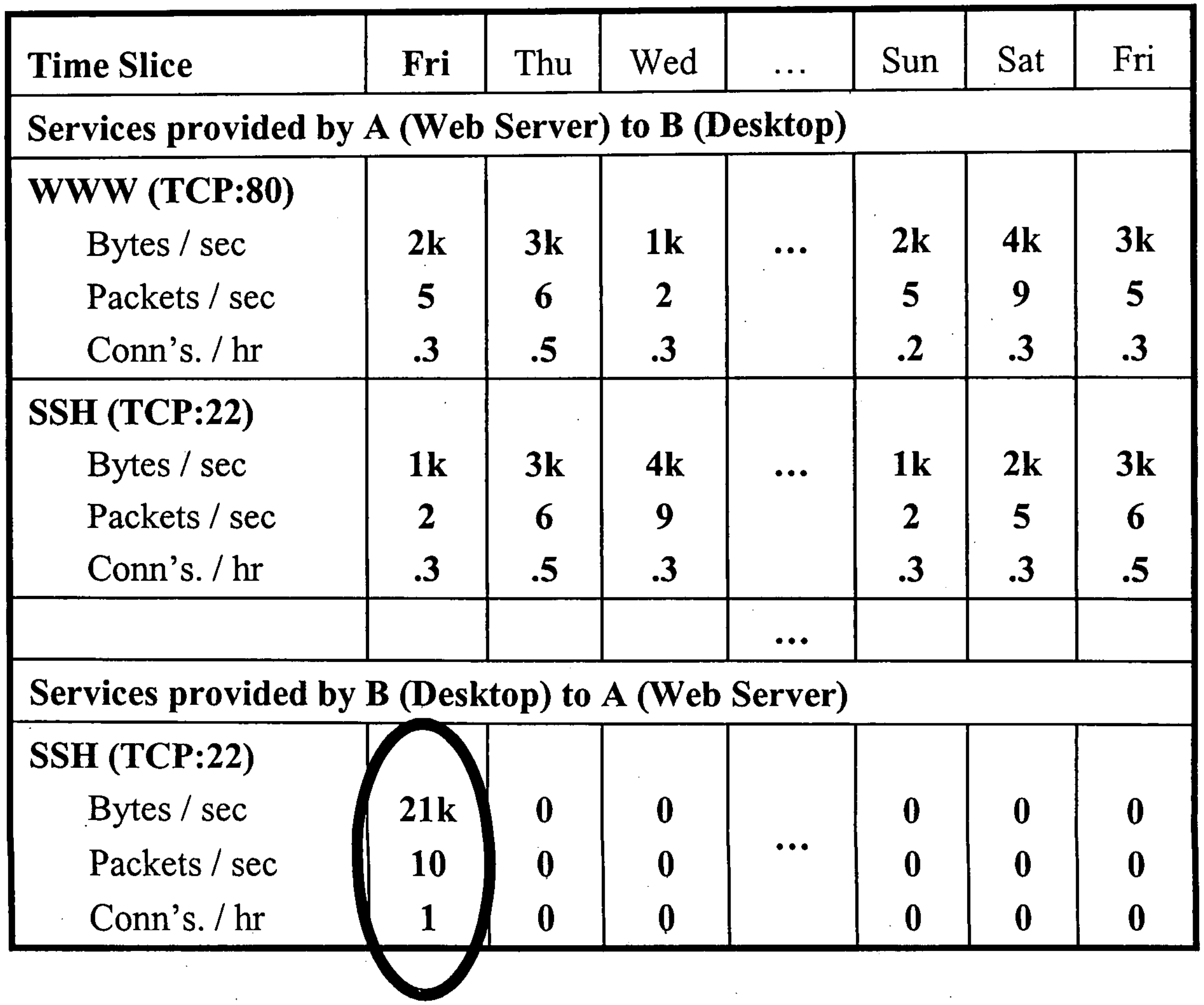

Aggregate statistics and host identifiers of peers, 44
41a
Host object, 43
Host ID
Aggregate statistics for host pairs, 46
41b
Host pair object, 45
Host ID, Host ID
Group Information, 47

FIG. 4A



Time Slice	Fri	Thu	Wed	…	Sun	Sat	Fri
Services provided by A (Web Server) to B (Desktop)							
WWW (TCP:80)							
Bytes / sec	**2k**	**3k**	**1k**	**…**	**2k**	**4k**	**3k**
Packets / sec	**5**	**6**	**2**		**5**	**9**	**5**
Conn's. / hr	**.3**	**.5**	**.3**		**.2**	**.3**	**.3**
SSH (TCP:22)							
Bytes / sec	**1k**	**3k**	**4k**	**…**	**1k**	**2k**	**3k**
Packets / sec	**2**	**6**	**9**		**2**	**5**	**6**
Conn's. / hr	**.3**	**.5**	**.3**		**.3**	**.3**	**.5**
				…			
Services provided by B (Desktop) to A (Web Server)							
SSH (TCP:22)							
Bytes / sec	**21k**	**0**	**0**	**…**	**0**	**0**	**0**
Packets / sec	**10**	**0**	**0**		**0**	**0**	**0**
Conn's. / hr	**1**	**0**	**0**		**0**	**0**	**0**

FIG. 5

FIG. 6

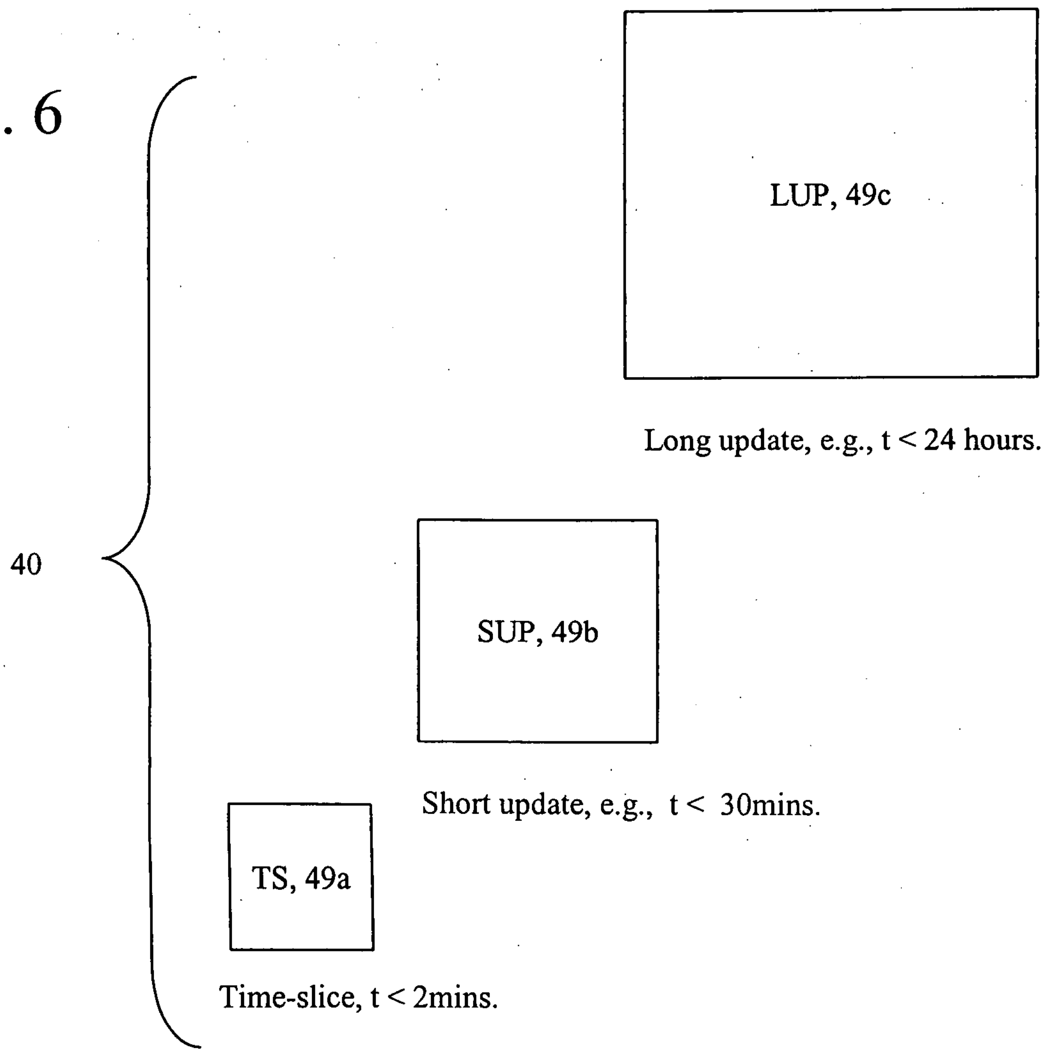

LUP, 49c
Long update, e.g., t < 24 hours.
SUP, 49b
Short update, e.g., t < 30mins.
TS, 49a
Time-slice, t < 2mins.
40

FIG. 7

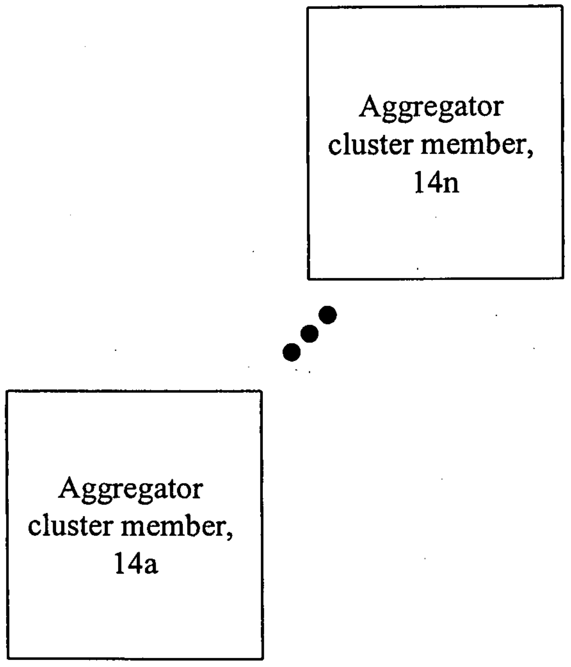
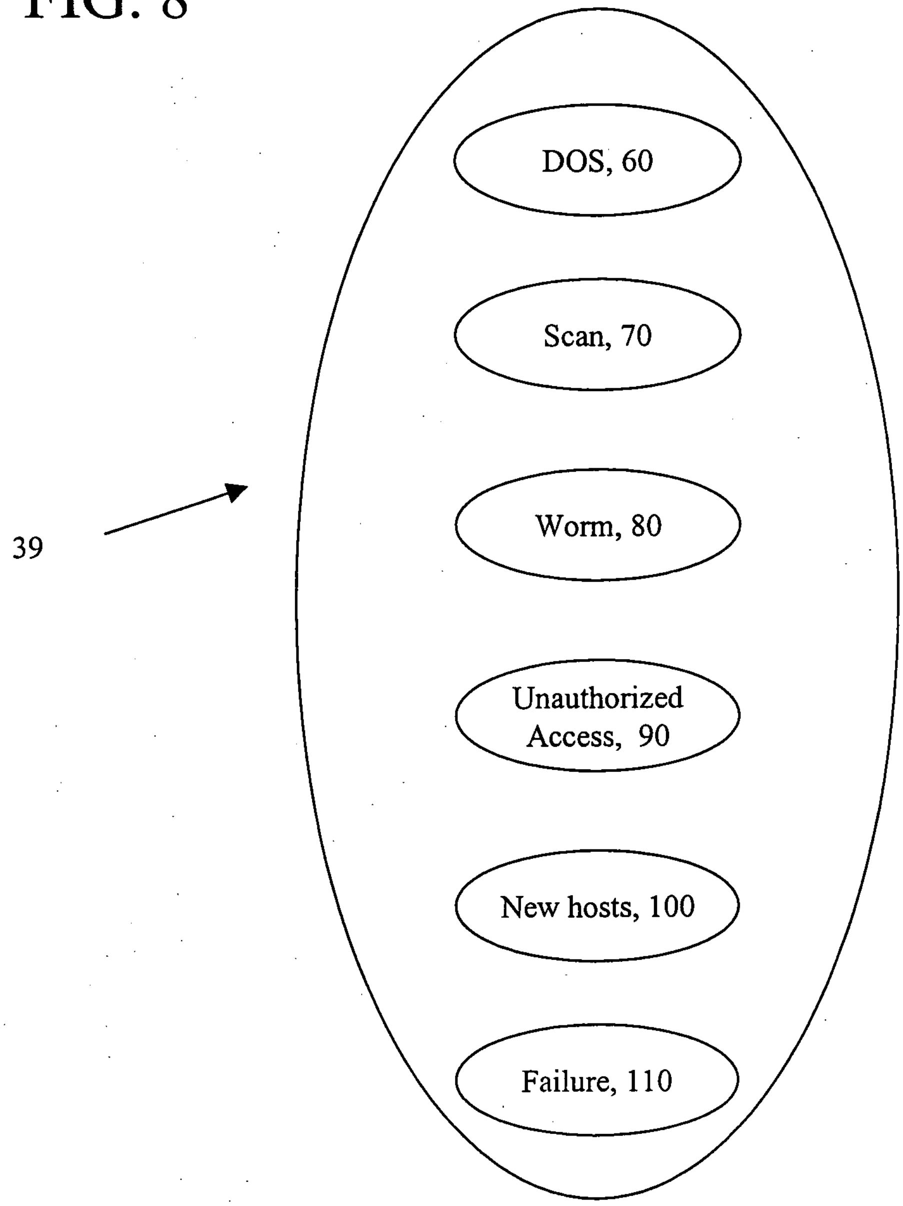

Aggregator cluster member, 14n
Aggregator cluster member, 14a

FIG. 8


DOS, 60
Scan, 70
Worm, 80
Unauthorized Access, 90
New hosts, 100
Failure, 110
39

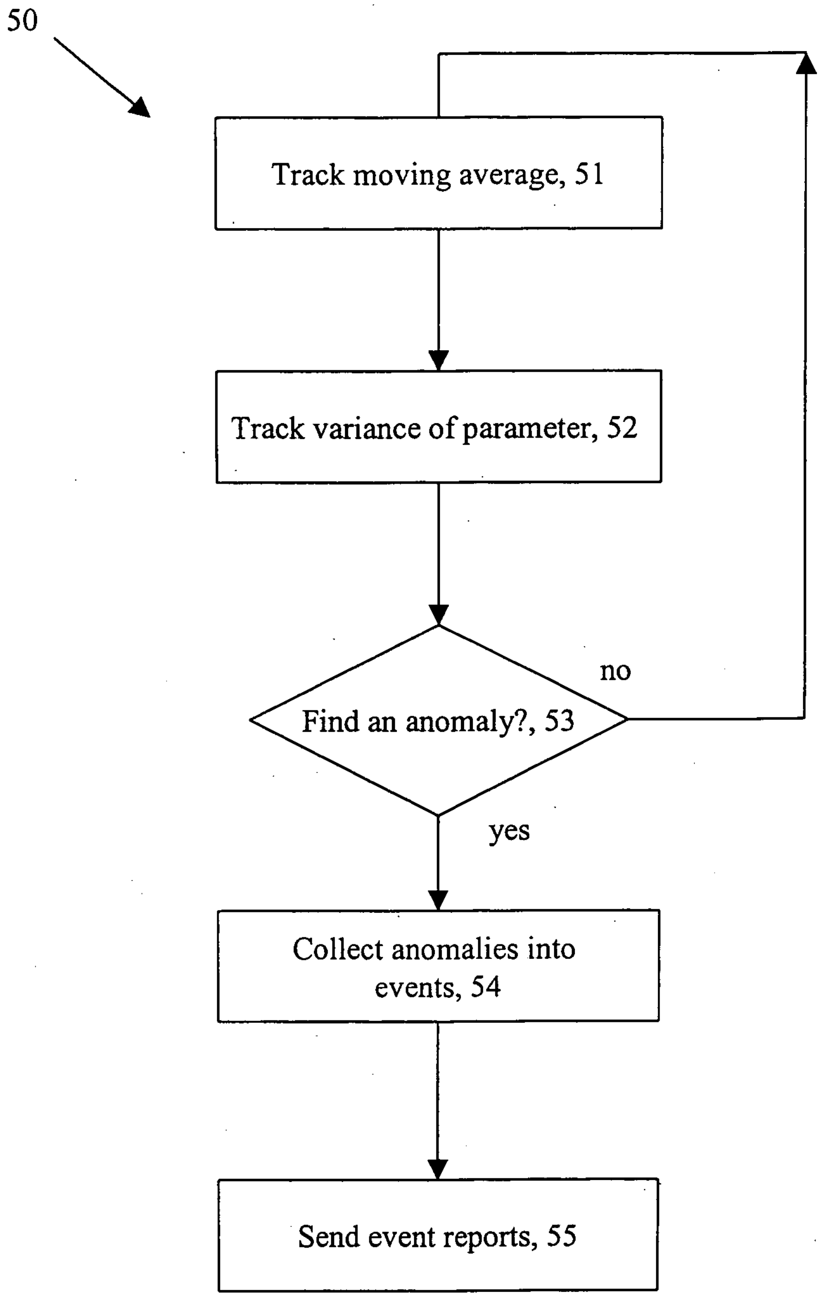

50
Track moving average, 51
Track variance of parameter, 52
Find an anomaly?, 53
no
yes
Collect anomalies into events, 54
Send event reports, 55

FIG. 9

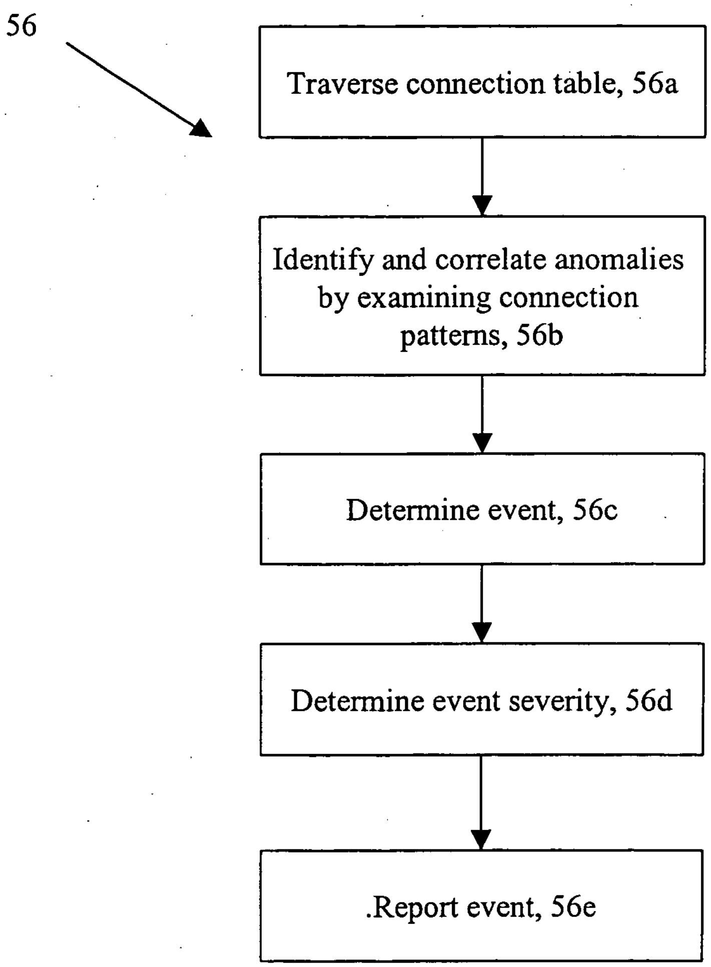

56
Traverse connection table, 56a
Identify and correlate anomalies by examining connection patterns, 56b
Determine event, 56c
Determine event severity, 56d
.Report event, 56e

FIG. 10

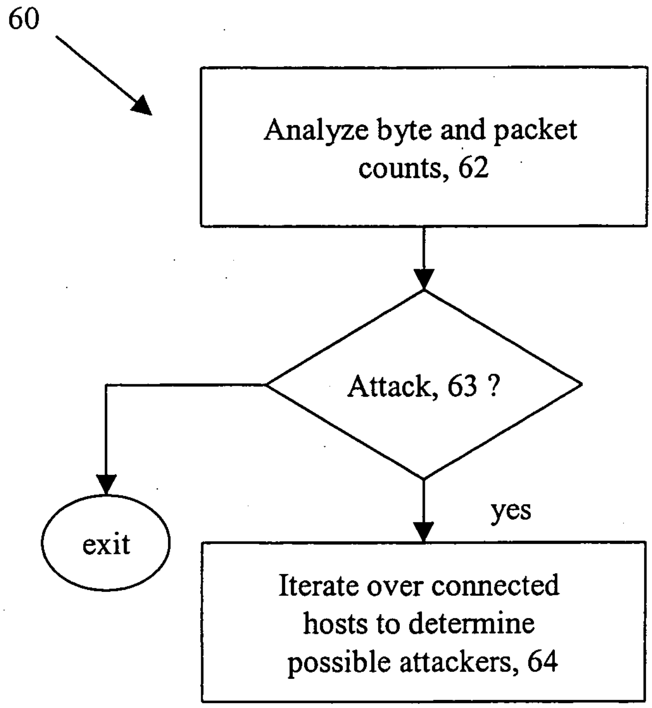

60
Analyze byte and packet counts, 62
Attack, 63 ?
exit
yes
Iterate over connected hosts to determine possible attackers, 64

FIG. 11

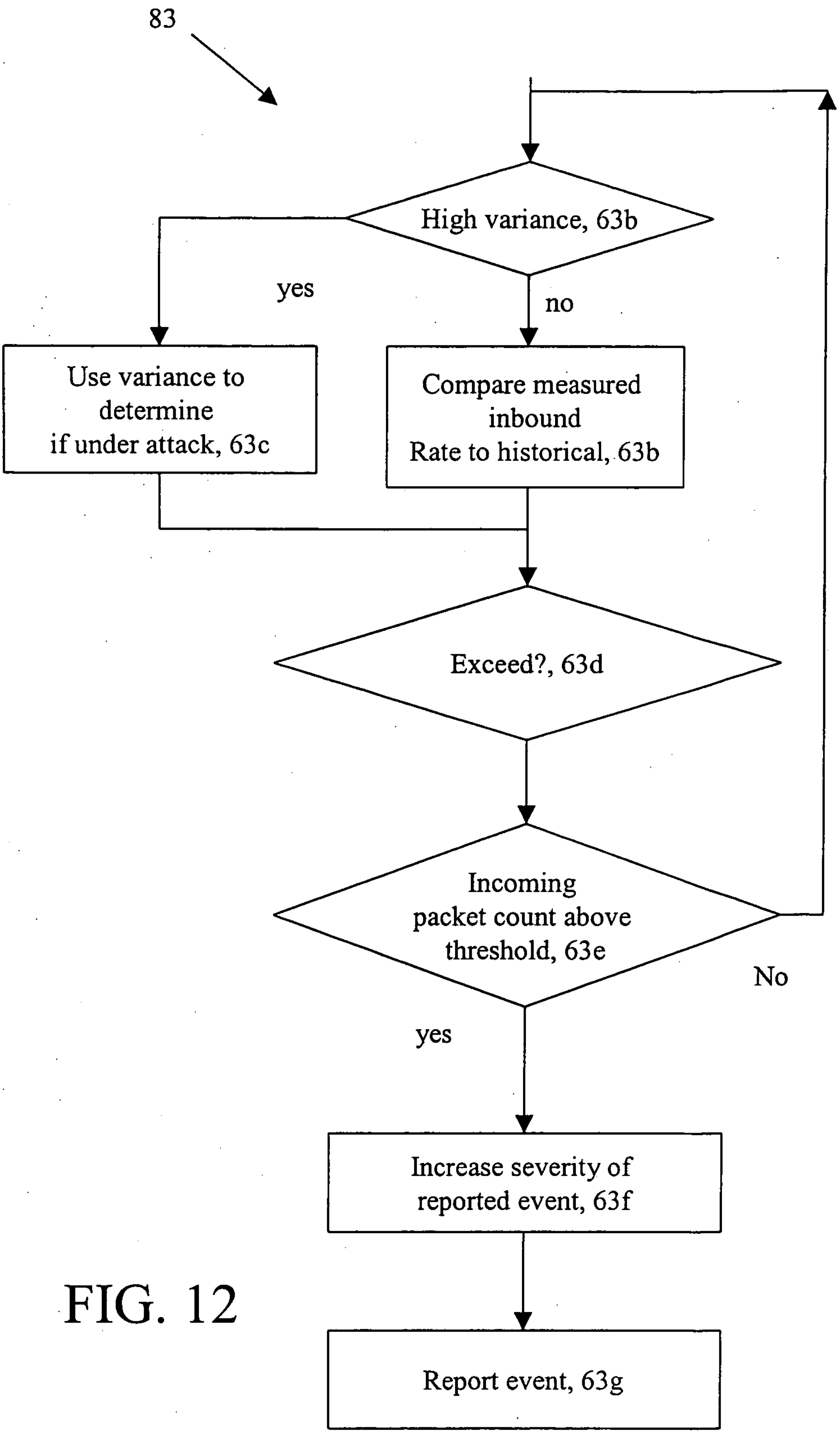

83
High variance, 63b
yes
no
Use variance to determine if under attack, 63c
Compare measured inbound Rate to historical, 63b
Exceed?, 63d
Incoming packet count above threshold, 63e
No
yes
Increase severity of reported event, 63f
Report event, 63g

FIG. 12

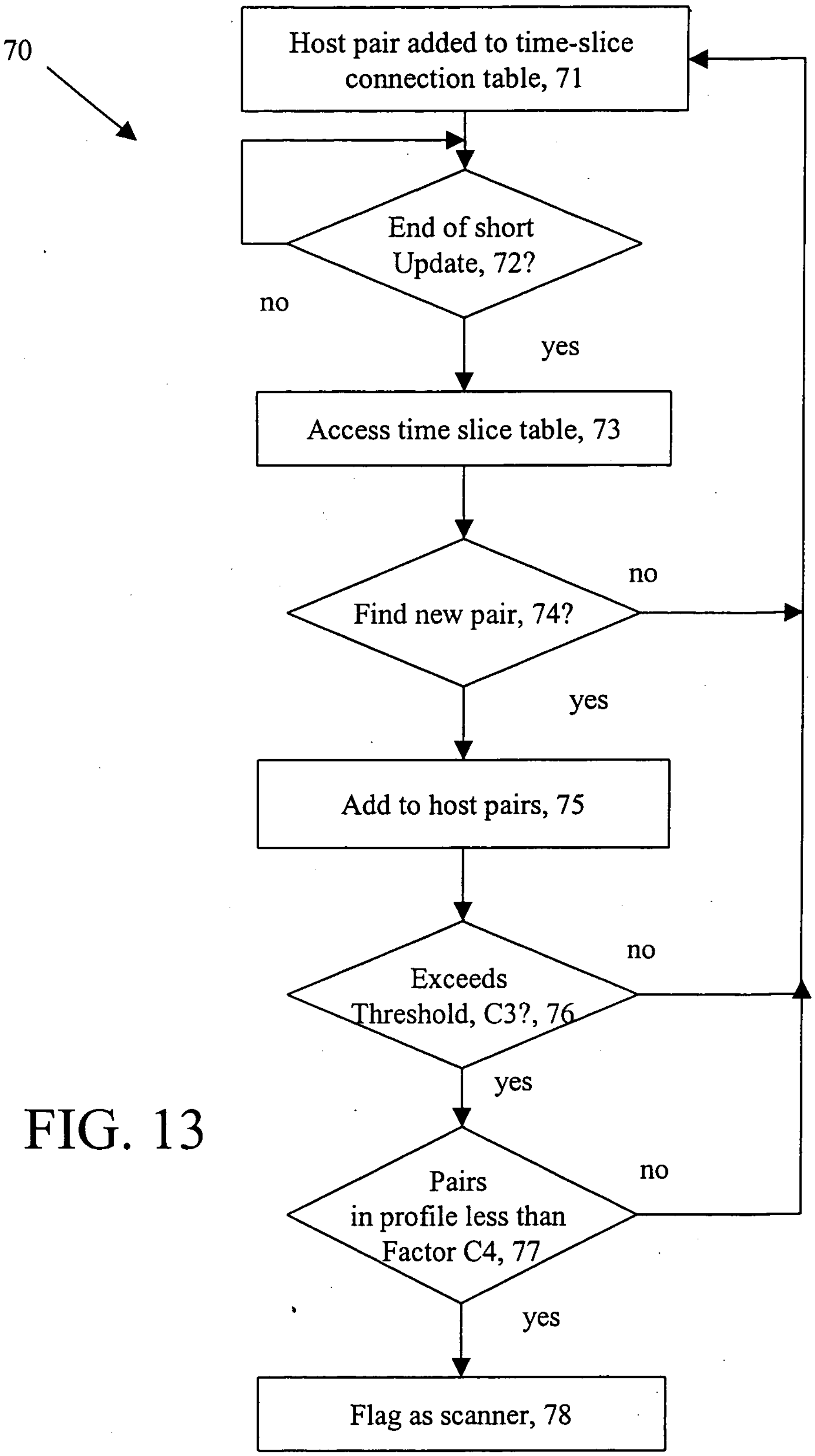

70
Host pair added to time-slice connection table, 71
End of short Update, 72?
no
yes
Access time slice table, 73
Find new pair, 74?
no
yes
Add to host pairs, 75
Exceeds Threshold, C3?, 76
no
yes
Pairs in profile less than Factor C4, 77
no
yes
Flag as scanner, 78

FIG. 13

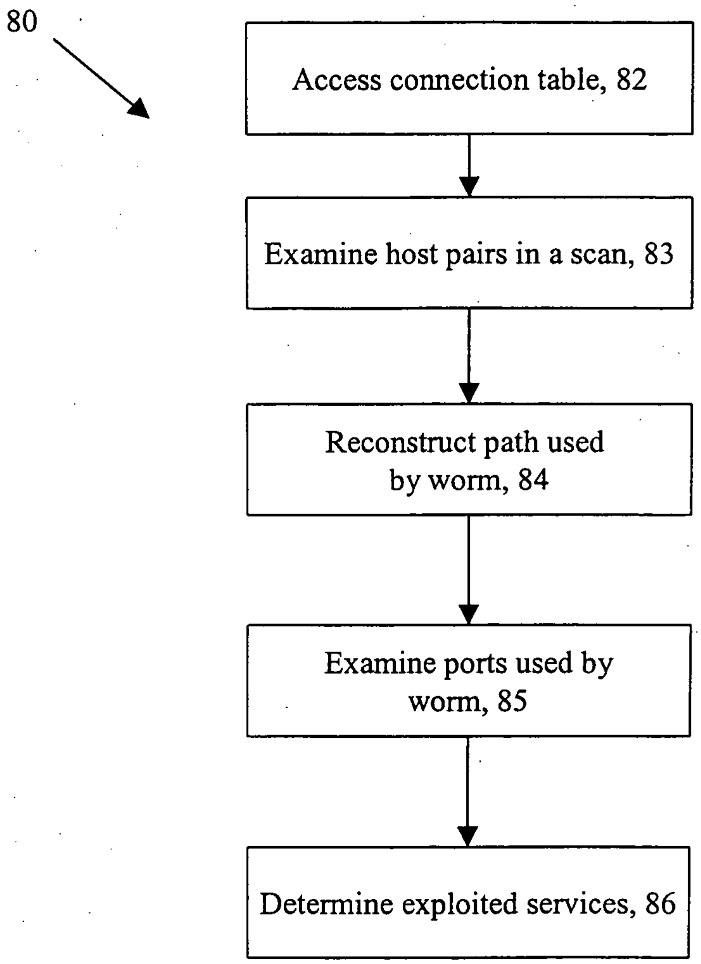

80
Access connection table, 82
Examine host pairs in a scan, 83
Reconstruct path used by worm, 84
Examine ports used by worm, 85
Determine exploited services, 86

FIG. 14

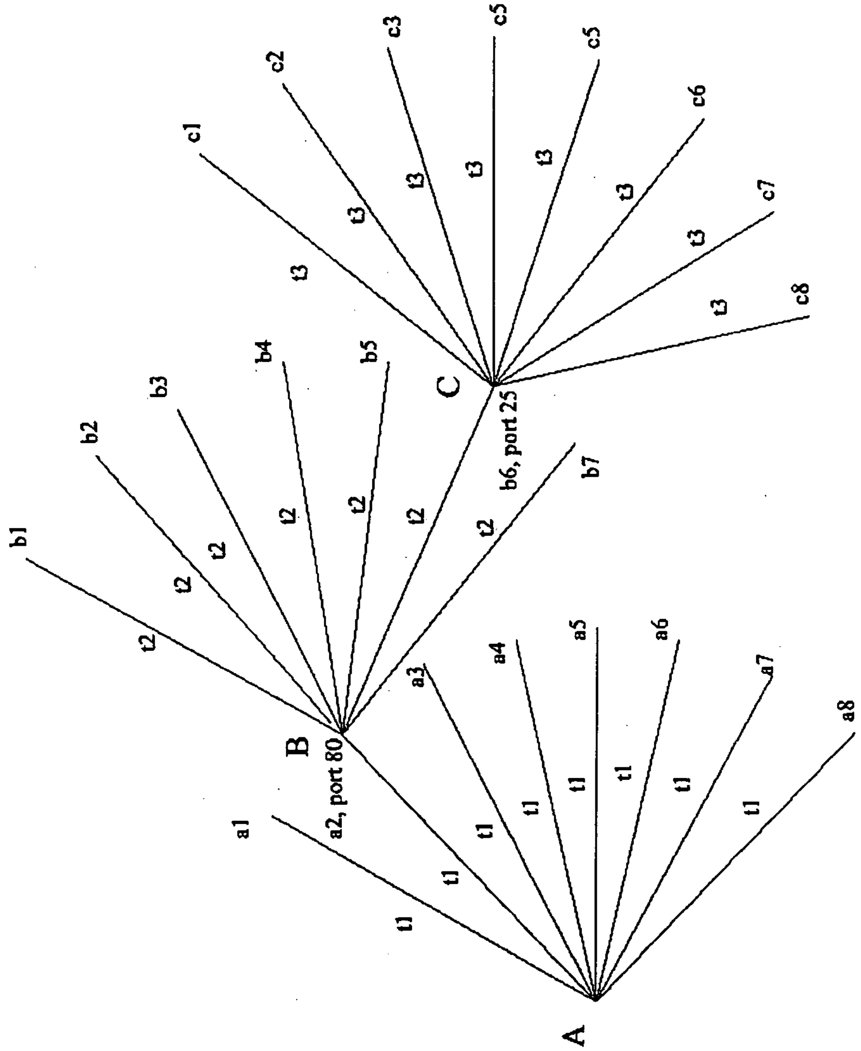

A
a1
t1
a2, port 80
t1
B
t1
a3
t1
a4
t1
a5
t1
a6
t1
a7
t1
a8
b1
t2
b2
t2
b3
t2
b4
t2
b5
t2
b6, port 25
t2
C
b7
t2
c1
t3
c2
t3
c3
t3
c5
t3
c5
t3
c6
t3
c7
t3
c8
t3

FIG. 15

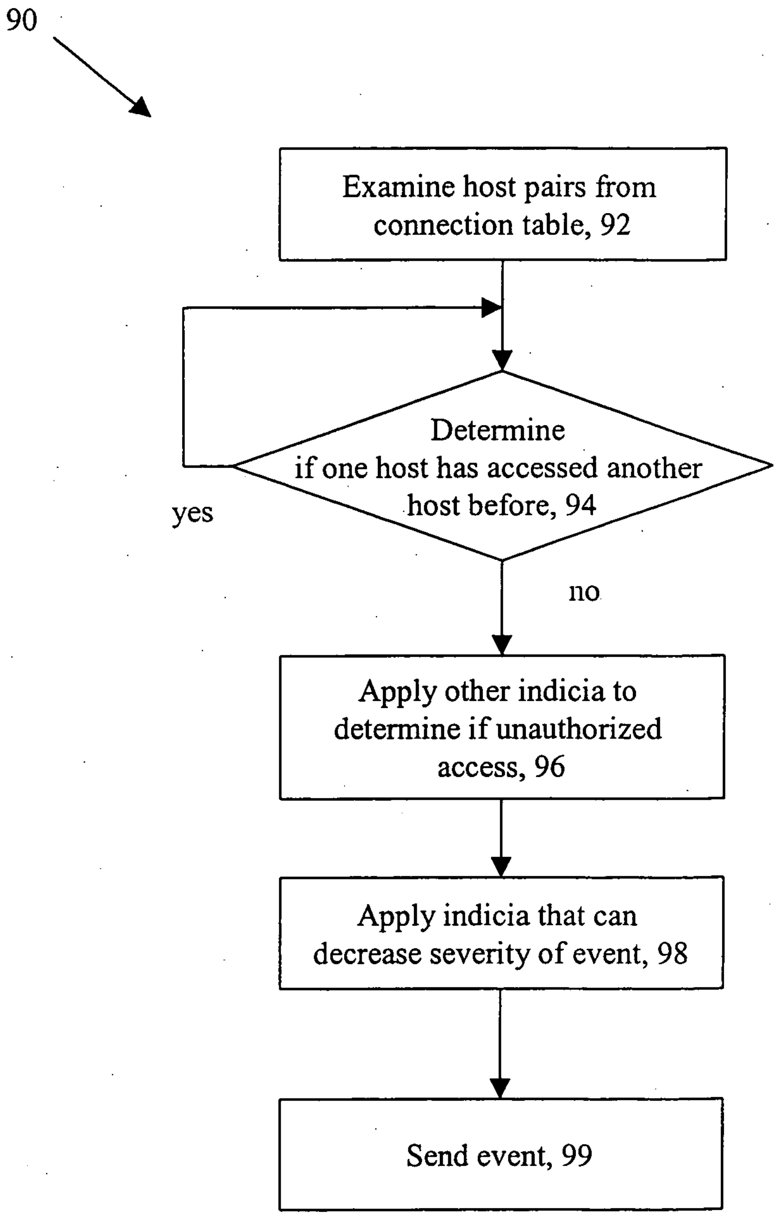

90
Examine host pairs from connection table, 92
Determine if one host has accessed another host before, 94
yes
no
Apply other indicia to determine if unauthorized access, 96
Apply indicia that can decrease severity of event, 98
Send event, 99

FIG. 16

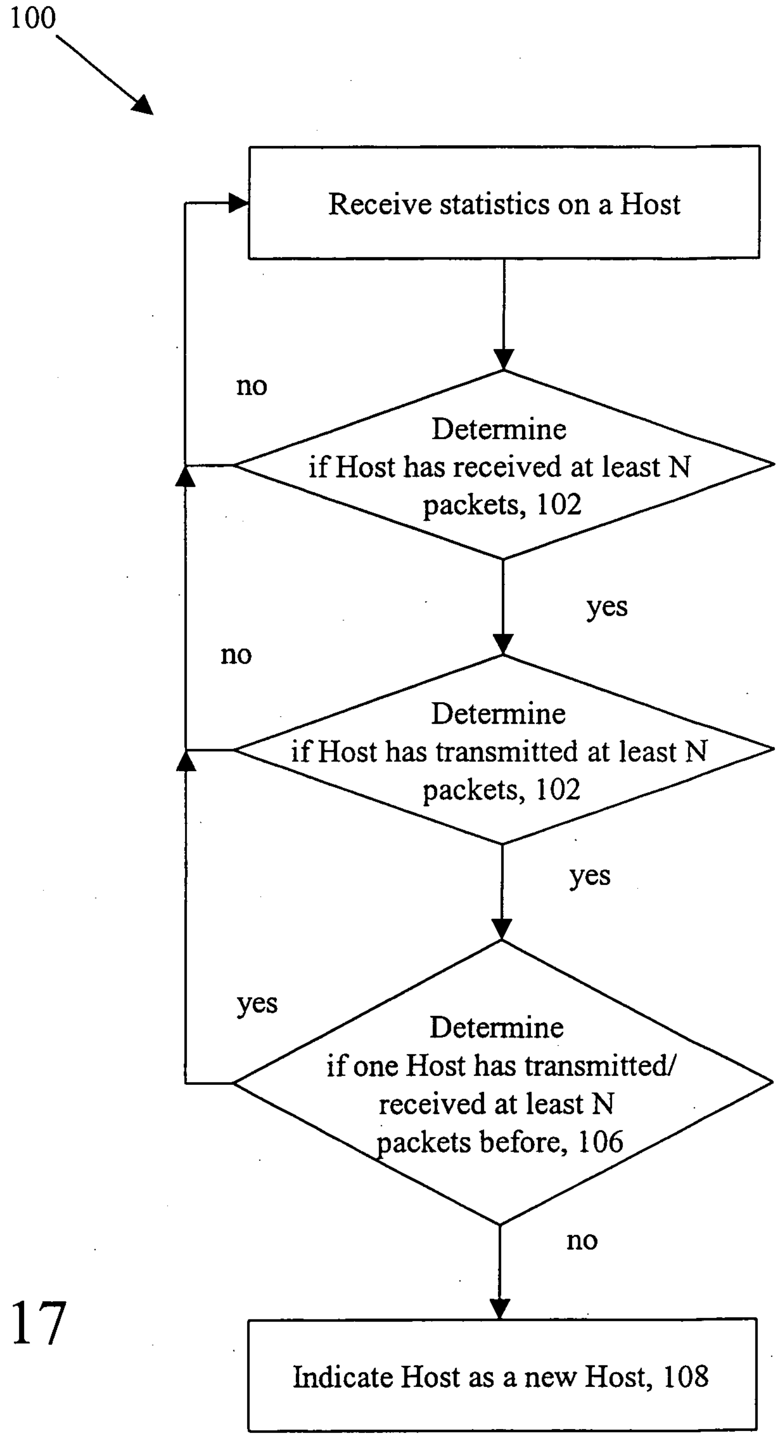

100
Receive statistics on a Host
no
Determine if Host has received at least N packets, 102
yes
no
Determine if Host has transmitted at least N packets, 102
yes
yes
Determine if one Host has transmitted/ received at least N packets before, 106
no
Indicate Host as a new Host, 108

FIG. 17

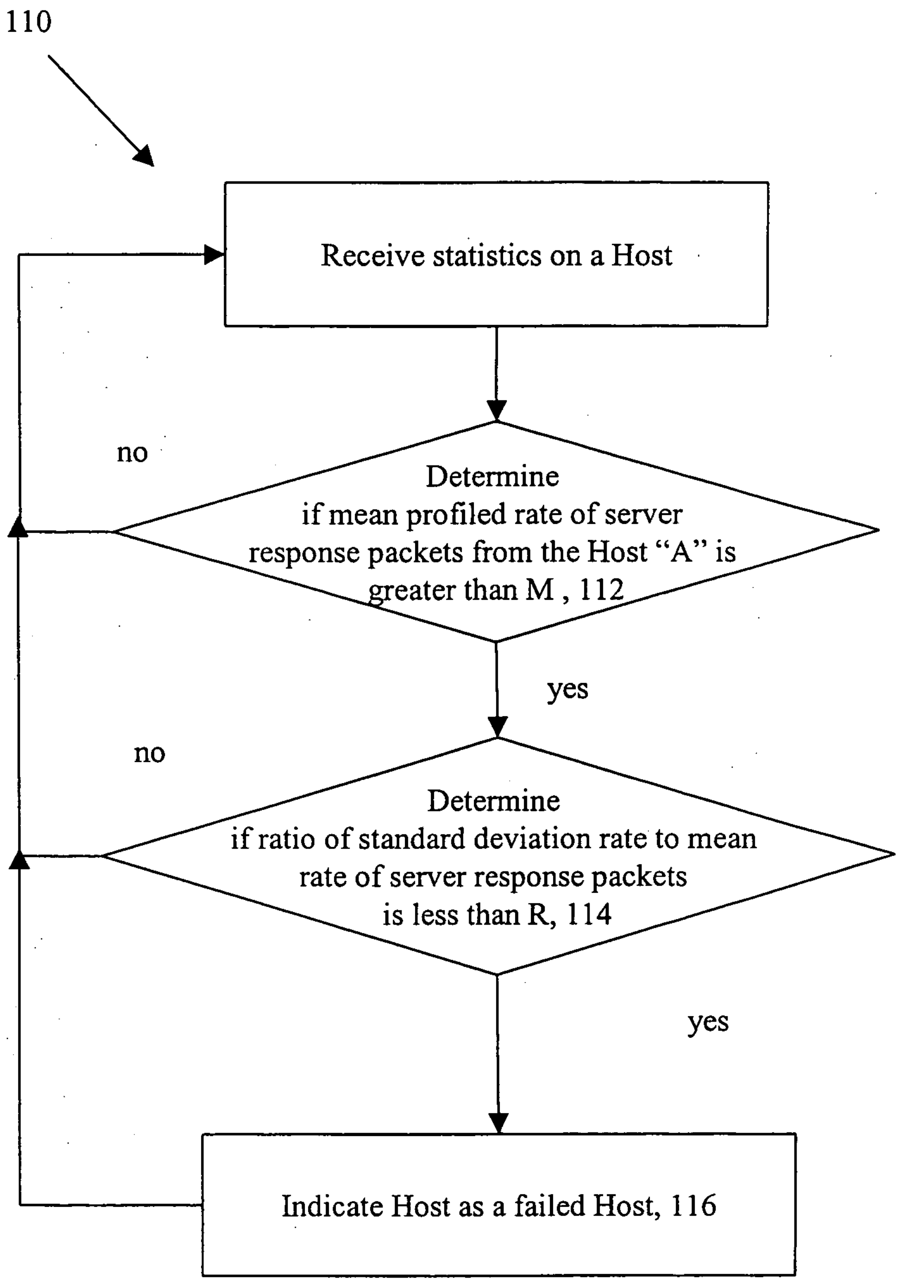

110
Receive statistics on a Host
Determine if mean profiled rate of server response packets from the Host "A" is greater than M , 112
no
yes
Determine if ratio of standard deviation rate to mean rate of server response packets is less than R, 114
no
yes
Indicate Host as a failed Host, 116

FIG. 18

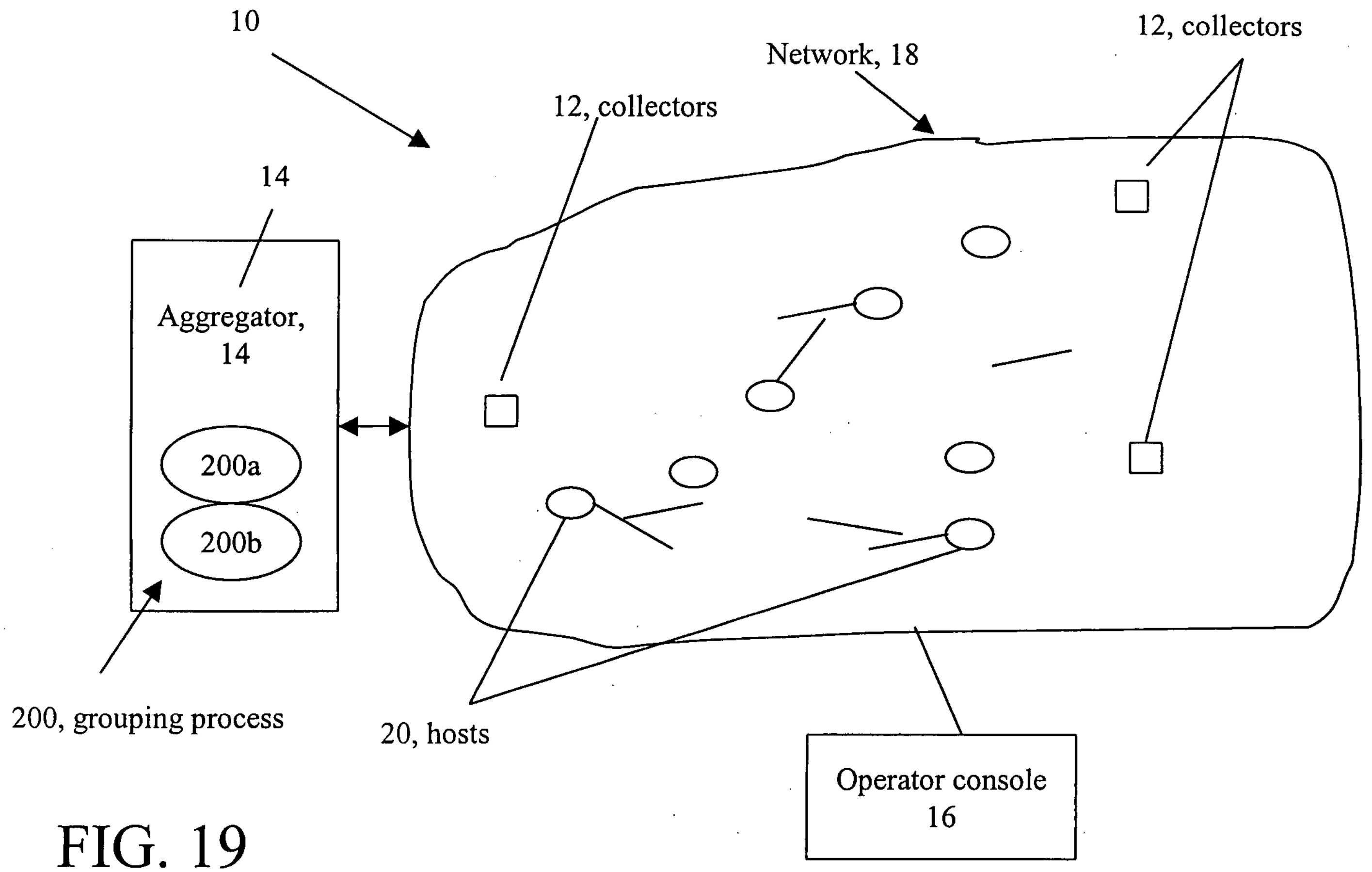

10
14
Aggregator,
14
200a
200b
200, grouping process
12, collectors
Network, 18
12, collectors
20, hosts
Operator console
16

FIG. 19

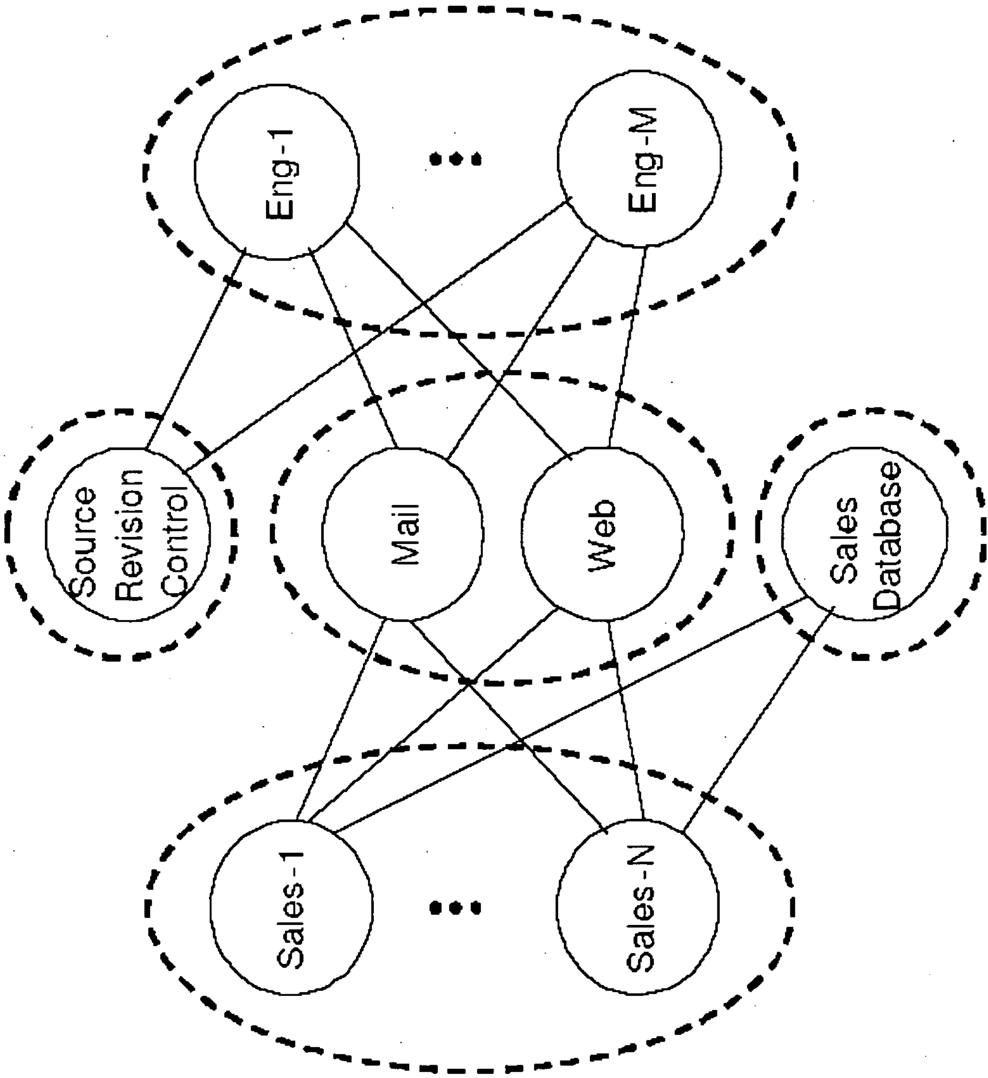

Eng-1
•••
Eng-M
Source Revision Control
Mail
Web
Sales Database
Sales-1
•••
Sales-N

FIG. 20

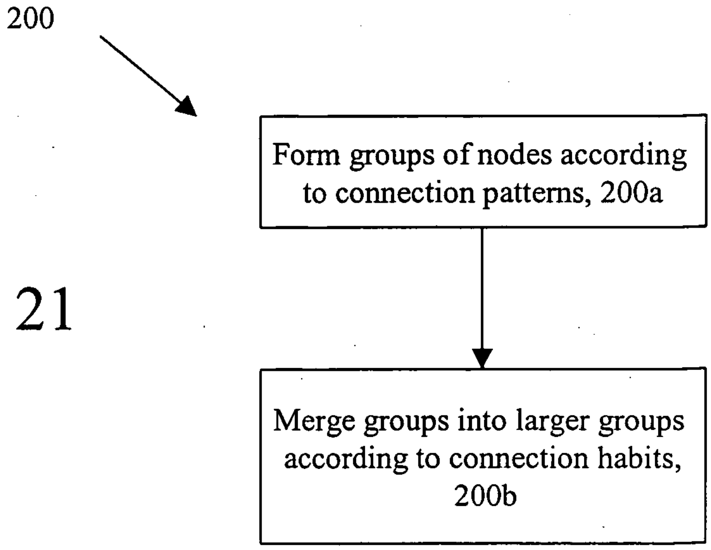

200
Form groups of nodes according to connection patterns, 200a
Merge groups into larger groups according to connection habits, 200b

FIG. 21

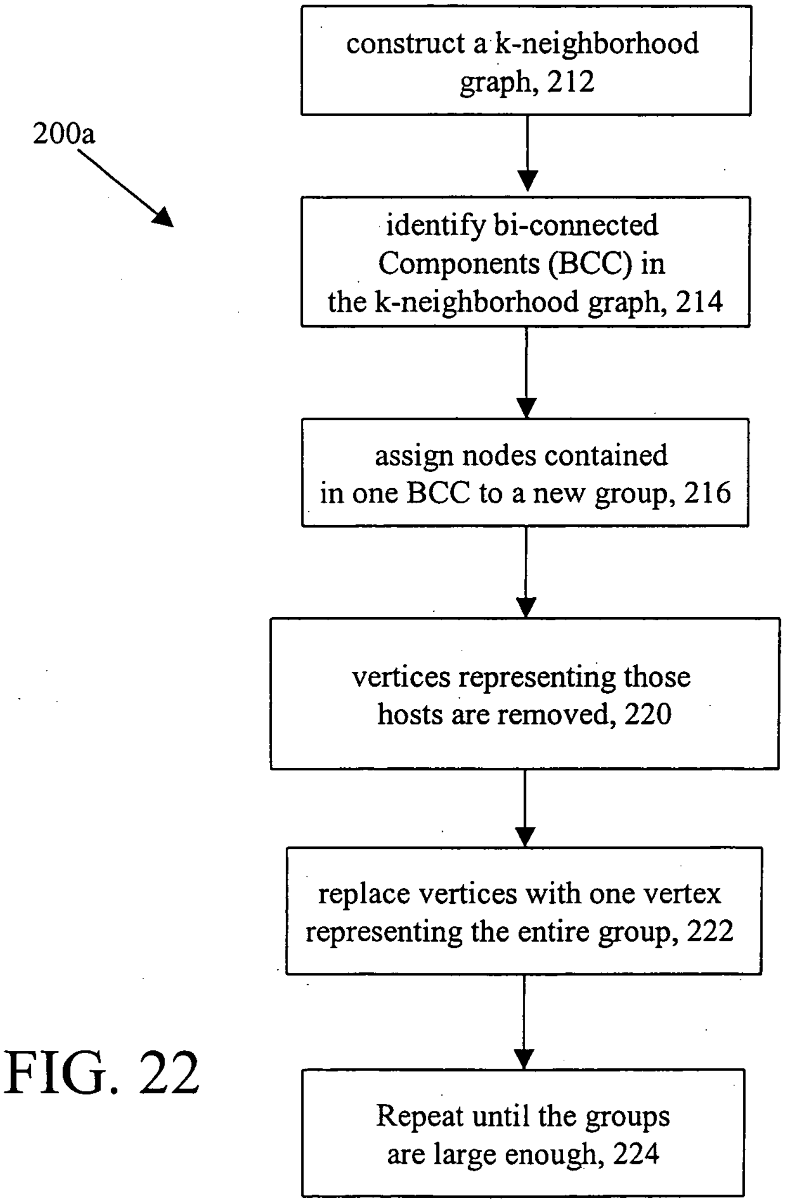

200a
construct a k-neighborhood graph, 212
identify bi-connected Components (BCC) in the k-neighborhood graph, 214
assign nodes contained in one BCC to a new group, 216
vertices representing those hosts are removed, 220
replace vertices with one vertex representing the entire group, 222
Repeat until the groups are large enough, 224

FIG. 22

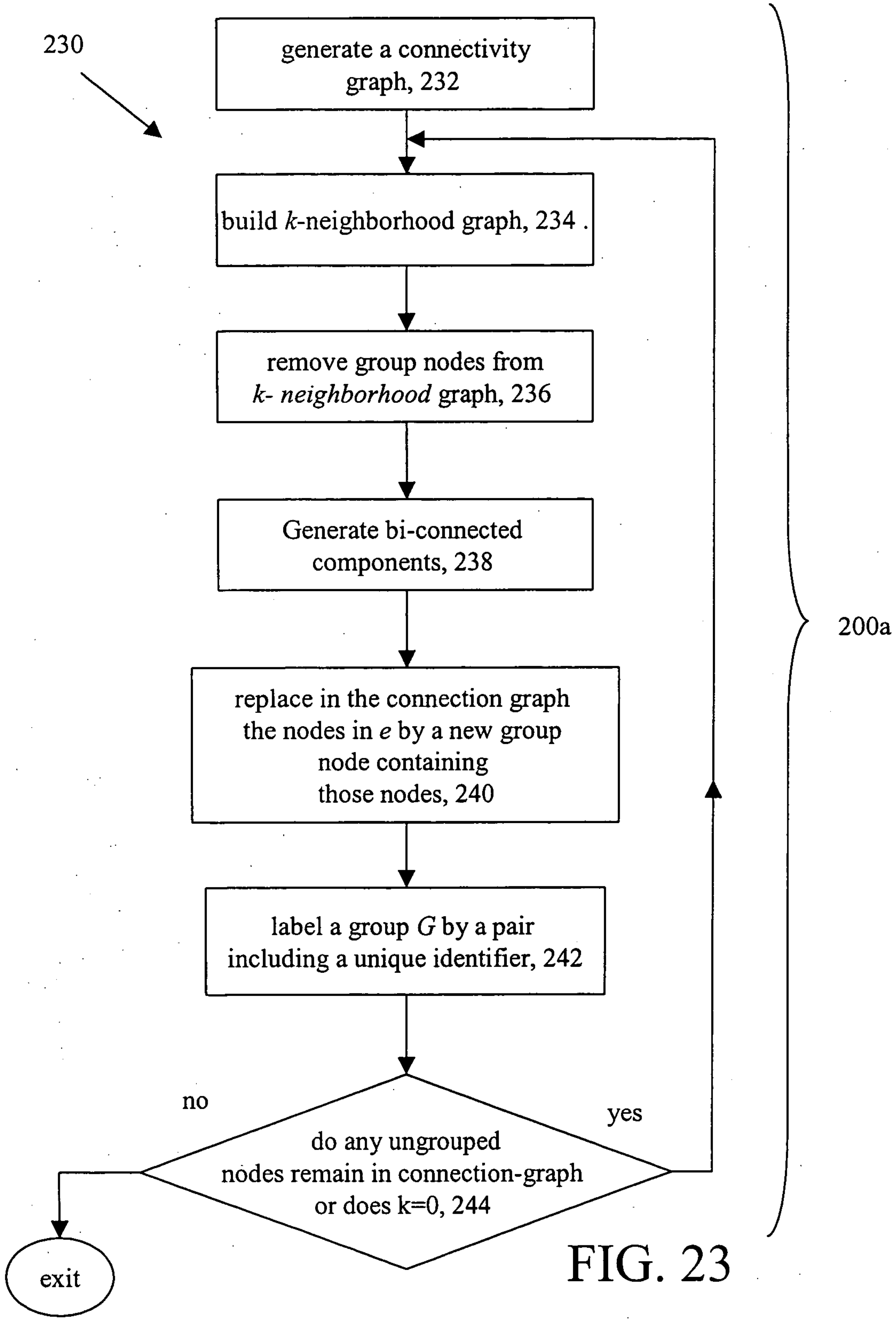

230
generate a connectivity graph, 232
build *k*-neighborhood graph, 234 .
remove group nodes from *k- neighborhood* graph, 236
Generate bi-connected components, 238
replace in the connection graph the nodes in *e* by a new group node containing those nodes, 240
label a group *G* by a pair including a unique identifier, 242
do any ungrouped nodes remain in connection-graph or does k=0, 244
no
yes
exit
200a

FIG. 23

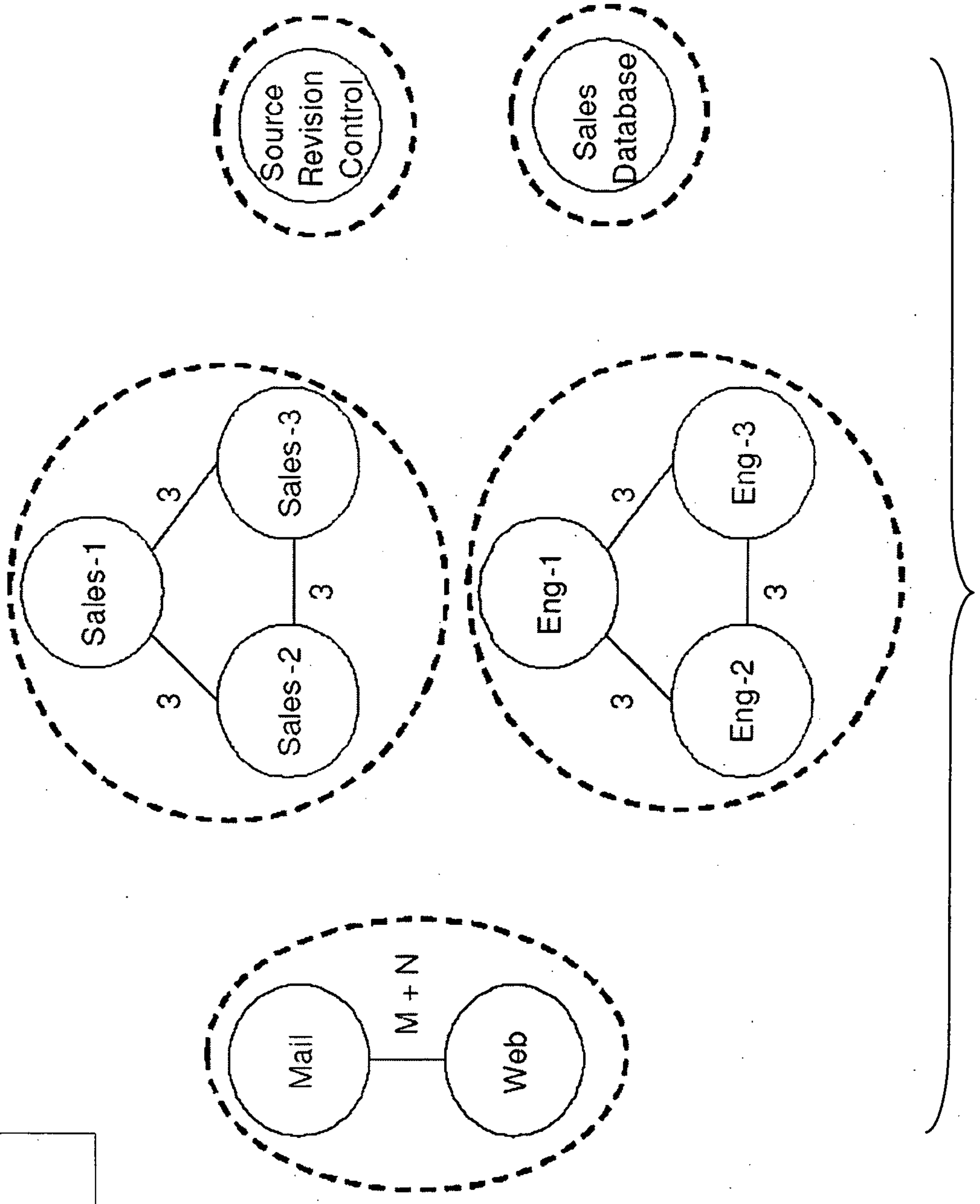

Source Revision Control
Sales Database
Sales-1
Sales-2
Sales-3
3
3
3
Eng-1
Eng-2
Eng-3
3
3
3
Mail
Web
M + N

FIG. 24

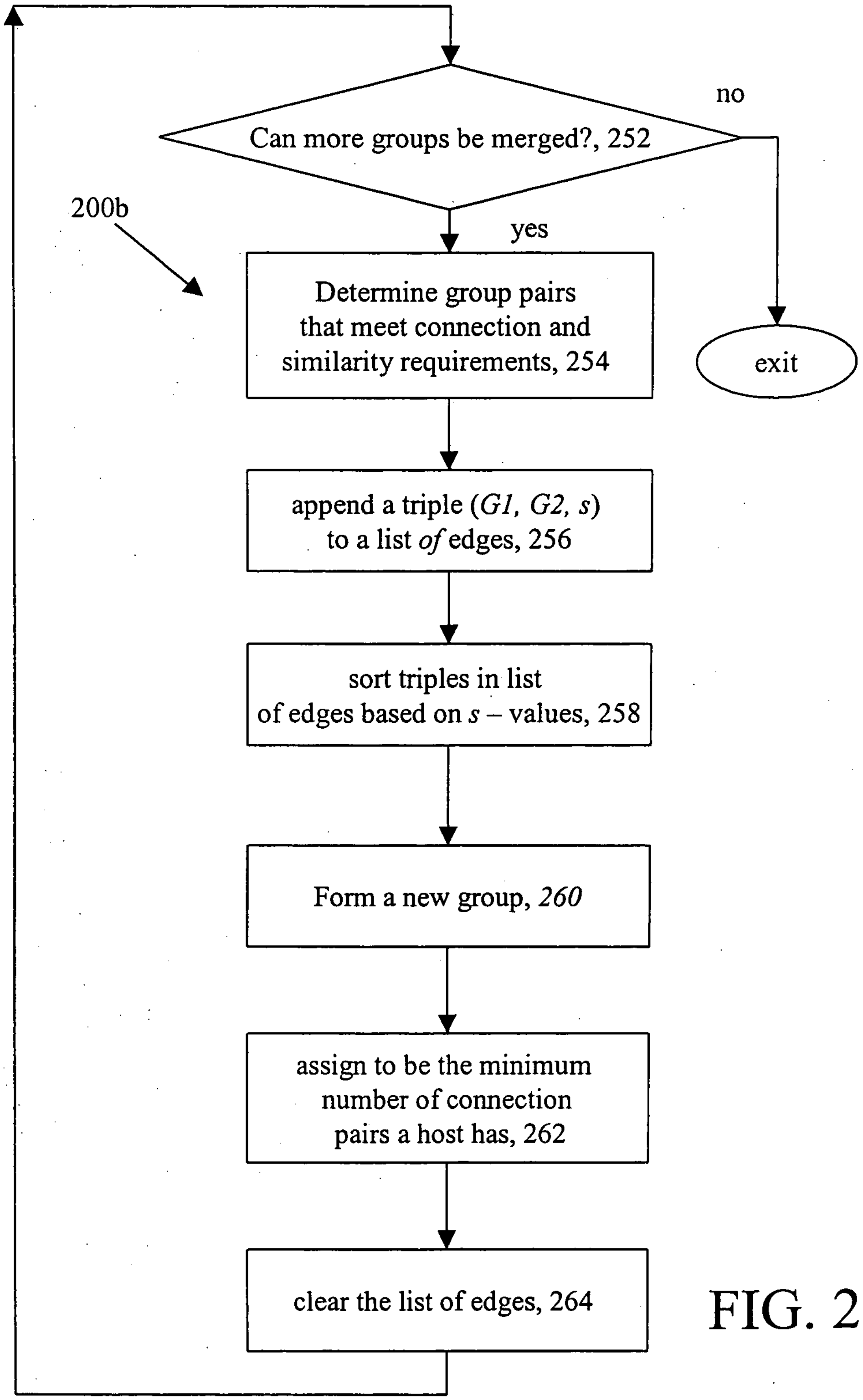

Can more groups be merged?, 252
no
yes
200b
Determine group pairs that meet connection and similarity requirements, 254
exit
append a triple (*G1, G2, s*) to a list *of* edges, 256
sort triples in list of edges based on *s* – values, 258
Form a new group, *260*
assign to be the minimum number of connection pairs a host has, 262
clear the list of edges, 264

FIG. 25

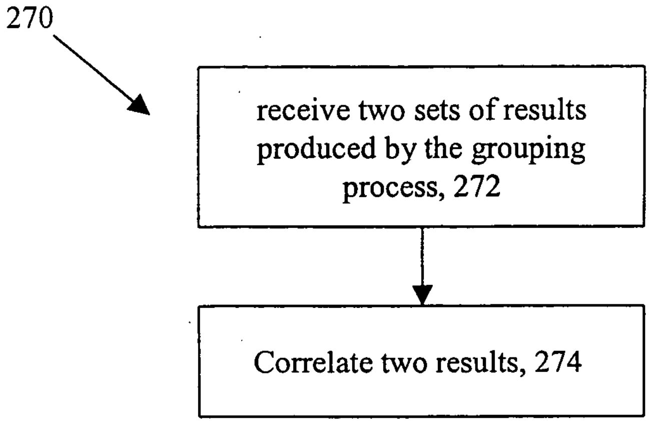

270
receive two sets of results produced by the grouping process, 272
Correlate two results, 274

FIG. 26

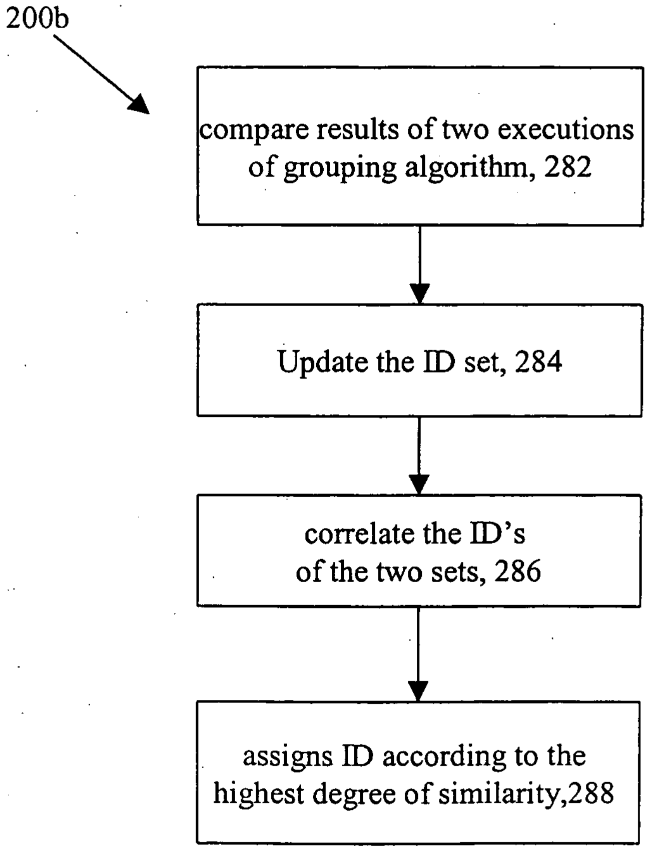

200b
compare results of two executions of grouping algorithm, 282
Update the ID set, 284
correlate the ID's of the two sets, 286
assigns ID according to the highest degree of similarity,288

FIG. 27

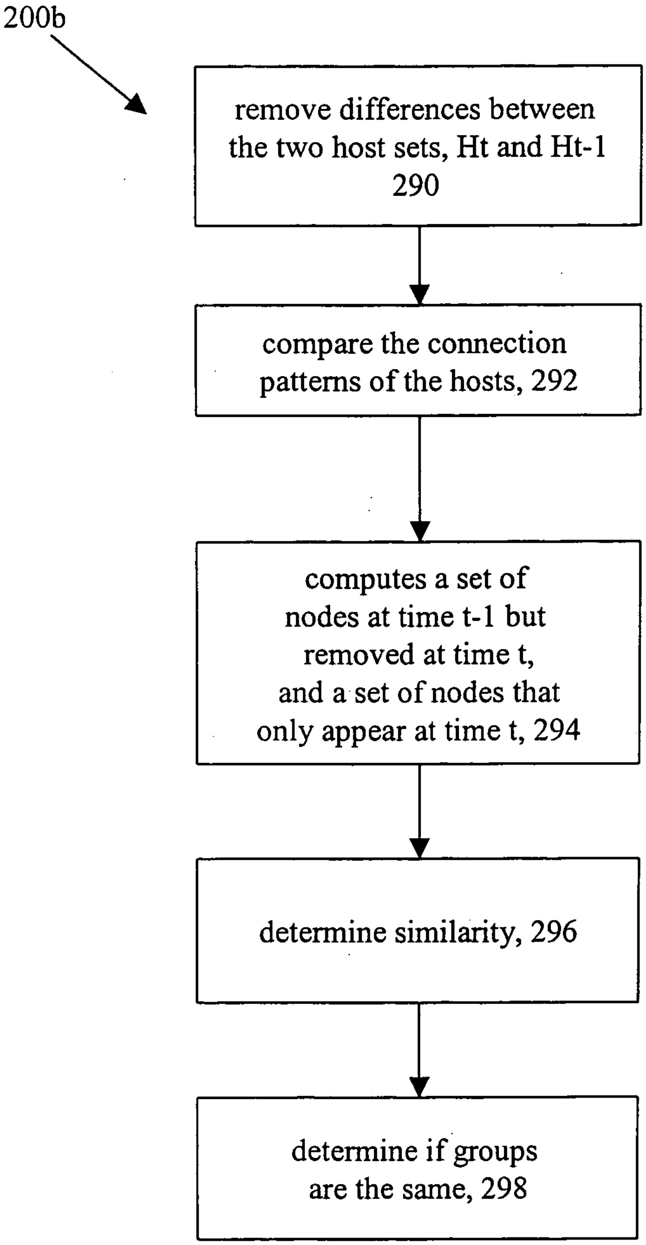
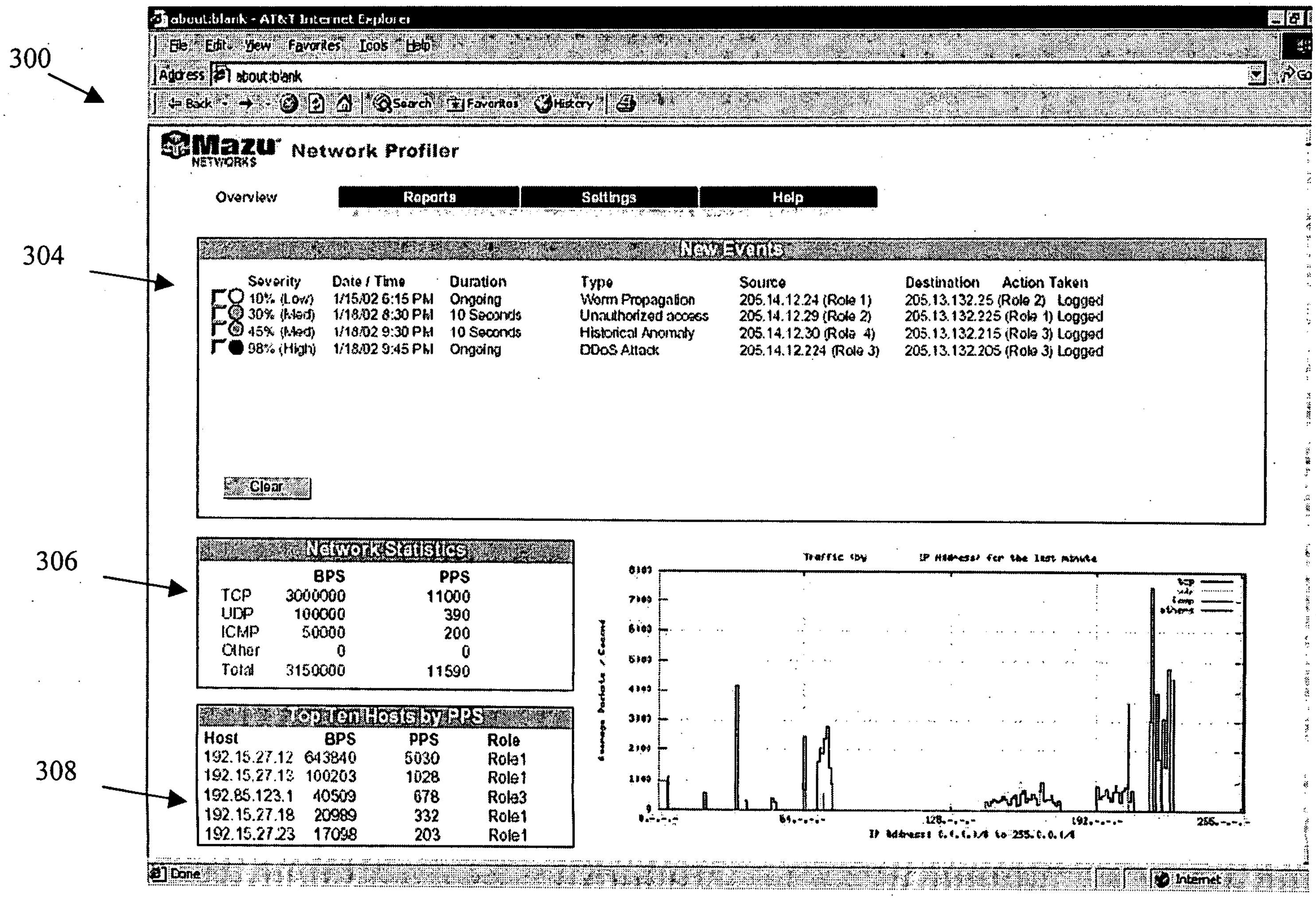

200b
remove differences between the two host sets, Ht and Ht-1 290
compare the connection patterns of the hosts, 292
computes a set of nodes at time t-1 but removed at time t, and a set of nodes that only appear at time t, 294
determine similarity, 296
determine if groups are the same, 298

FIG. 28

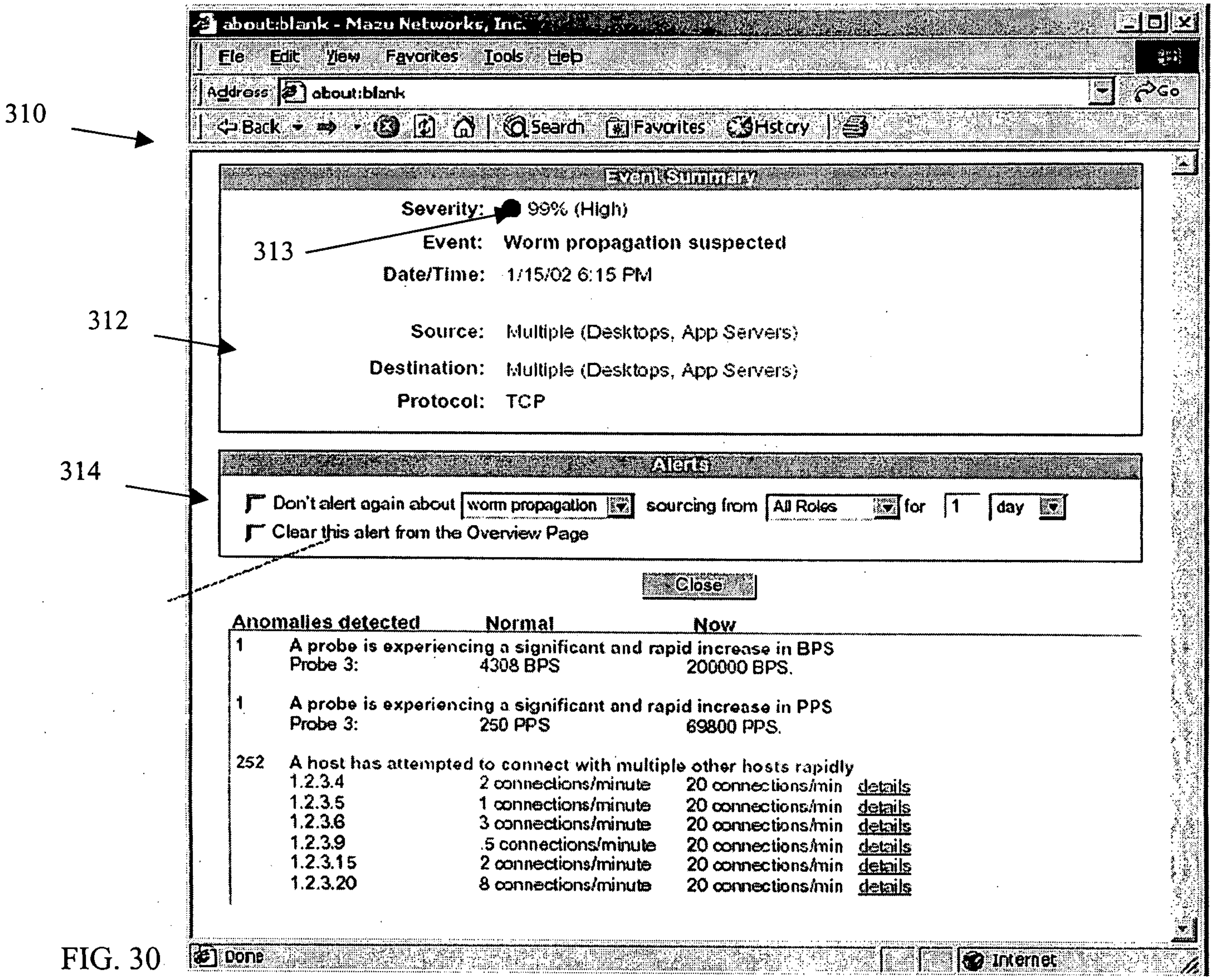


Severity	Date / Time	Duration	Type	Source	Destination	Action Taken
○ 10% (Low)	1/15/02 6:15 PM	Ongoing	Worm Propagation	205.14.12.24 (Role 1)	205.13.132.25 (Role 2)	Logged
◎ 30% (Med)	1/18/02 8:30 PM	10 Seconds	Unauthorized access	205.14.12.29 (Role 2)	205.13.132.225 (Role 1)	Logged
◎ 45% (Med)	1/18/02 9:30 PM	10 Seconds	Historical Anomaly	205.14.12.30 (Role 4)	205.13.132.215 (Role 3)	Logged
● 98% (High)	1/18/02 9:45 PM	Ongoing	DDoS Attack	205.14.12.224 (Role 3)	205.13.132.205 (Role 3)	Logged

	BPS	PPS
TCP	3000000	11000
UDP	100000	390
ICMP	50000	200
Other	0	0
Total	3150000	11590

Host	BPS	PPS	Role
192.15.27.12	643840	5030	Role1
192.15.27.13	100203	1028	Role1
192.85.123.1	40509	678	Role3
192.15.27.18	20989	332	Role1
192.15.27.23	17098	203	Role1

FIG. 29



Severity: ● 99% (High)

Event: Worm propagation suspected

Date/Time: 1/15/02 6:15 PM

Source: Multiple (Desktops, App Servers)

Destination: Multiple (Desktops, App Servers)

Protocol: TCP

□ Don't alert again about worm propagation sourcing from All Roles for 1 day

□ Clear this alert from the Overview Page

Anomalies detected		Normal	Now	
1	A probe is experiencing a significant and rapid increase in BPS			
	Probe 3:	4308 BPS	200000 BPS.	
1	A probe is experiencing a significant and rapid increase in PPS			
	Probe 3:	250 PPS	69800 PPS.	
252	A host has attempted to connect with multiple other hosts rapidly			
	1.2.3.4	2 connections/minute	20 connections/min	details
	1.2.3.5	1 connections/minute	20 connections/min	details
	1.2.3.6	3 connections/minute	20 connections/min	details
	1.2.3.9	.5 connections/minute	20 connections/min	details
	1.2.3.15	2 connections/minute	20 connections/min	details
	1.2.3.20	8 connections/minute	20 connections/min	details

FIG. 30

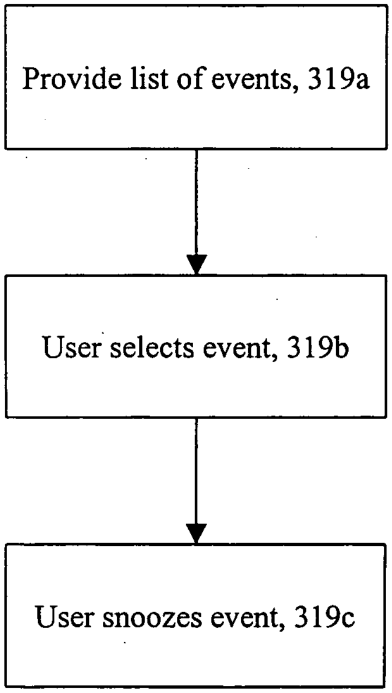
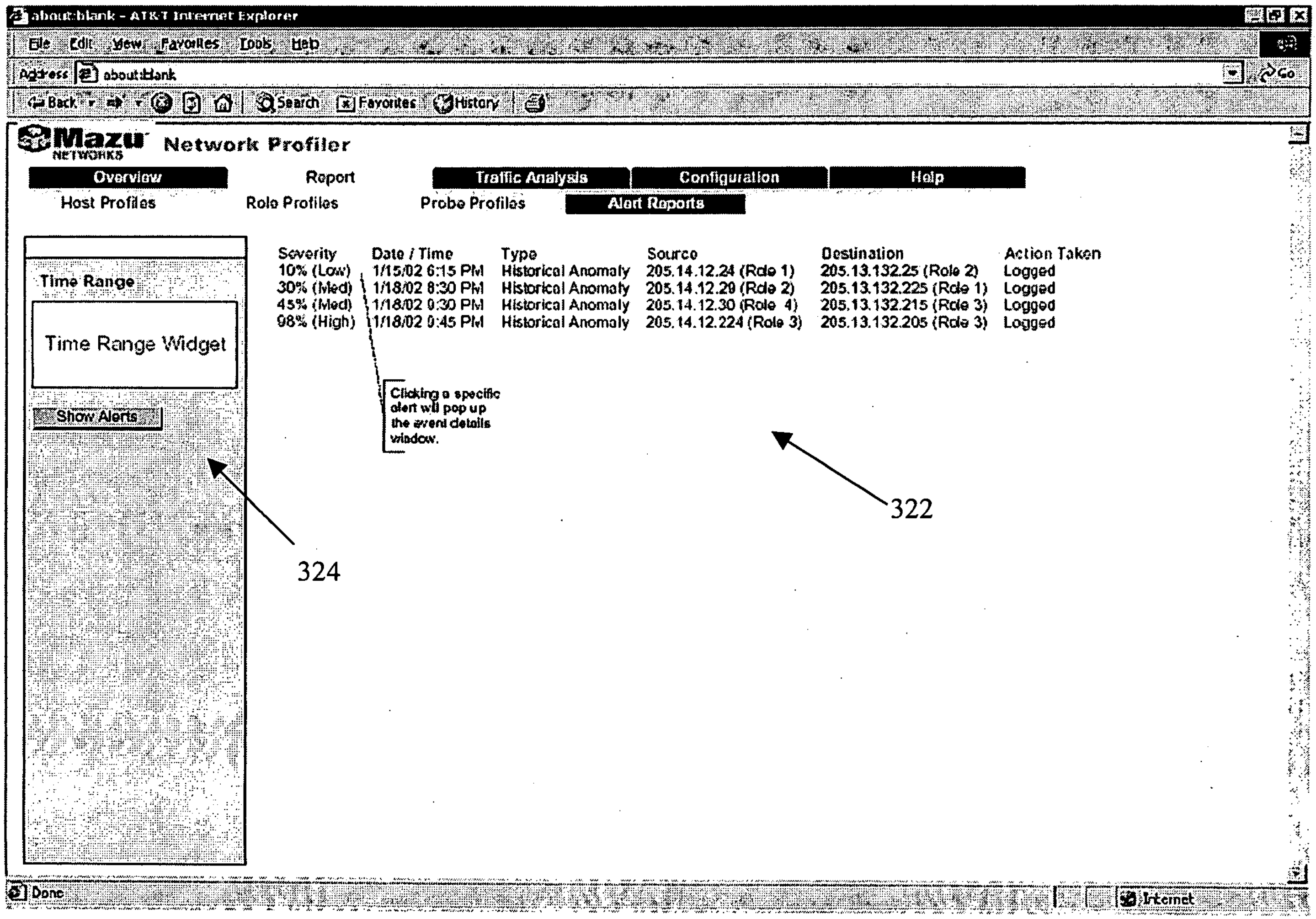

Provide list of events, 319a
User selects event, 319b
User snoozes event, 319c

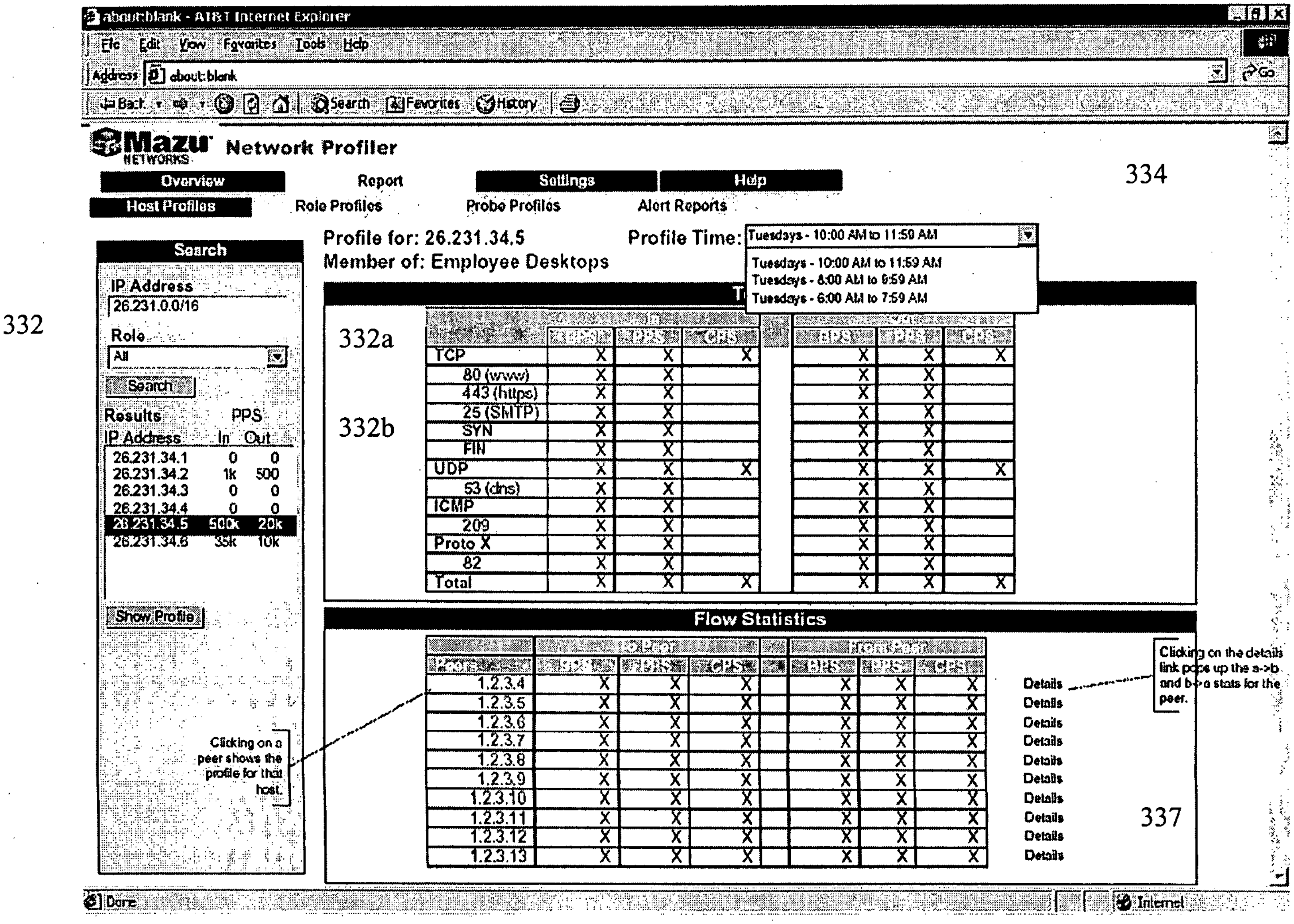
FIG. 31



Severity	Date / Time	Type	Source	Destination	Action Taken
10% (Low)	1/15/02 6:15 PM	Historical Anomaly	205.14.12.24 (Role 1)	205.13.132.25 (Role 2)	Logged
30% (Med)	1/18/02 8:30 PM	Historical Anomaly	205.14.12.29 (Role 2)	205.13.132.225 (Role 1)	Logged
45% (Med)	1/18/02 0:30 PM	Historical Anomaly	205.14.12.30 (Role 4)	205.13.132.215 (Role 3)	Logged
98% (High)	1/18/02 0:45 PM	Historical Anomaly	205.14.12.224 (Role 3)	205.13.132.205 (Role 3)	Logged

Clicking a specific alert will pop up the event details window.

FIG. 32



Profile for: 26.231.34.5
Member of: Employee Desktops

Profile Time: Tuesdays - 10:00 AM to 11:59 AM

Tuesdays - 10:00 AM to 11:59 AM
Tuesdays - 8:00 AM to 9:59 AM
Tuesdays - 6:00 AM to 7:59 AM

IP Address: 26.231.0.0/16

Role: All

IP Address	PPS In	PPS Out
26.231.34.1	0	0
26.231.34.2	1k	500
26.231.34.3	0	0
26.231.34.4	0	0
26.231.34.5	500k	20k
26.231.34.6	35k	10k

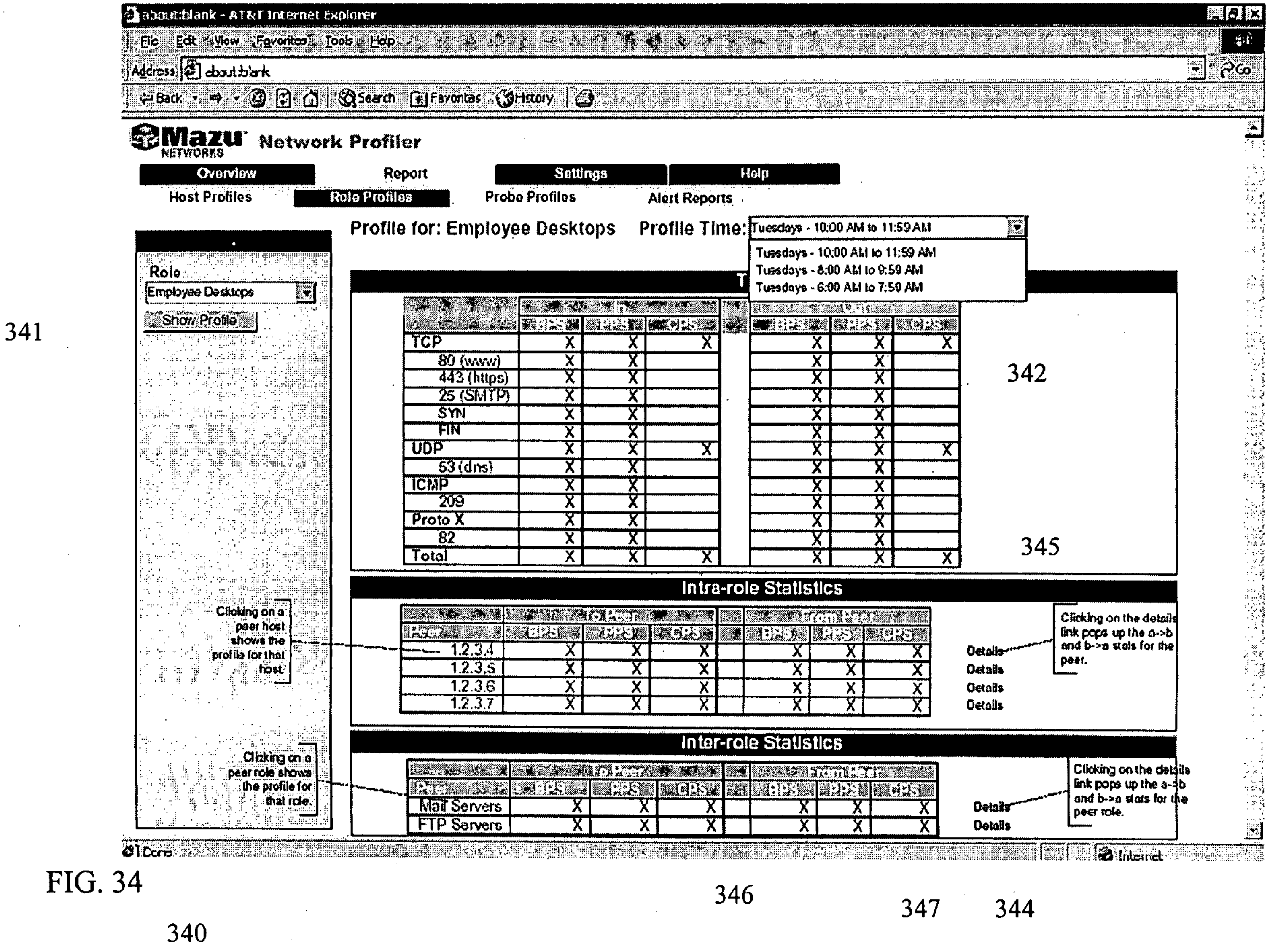
	In				Out		
[illegible]	BPS	PPS	CPS		BPS	PPS	CPS
TCP	X	X	X		X	X	X
80 (www)	X	X			X	X	
443 (https)	X	X			X	X	
25 (SMTP)	X	X			X	X	
SYN	X	X			X	X	
FIN	X	X			X	X	
UDP	X	X	X		X	X	X
53 (dns)	X	X			X	X	
ICMP	X	X			X	X	
209	X	X			X	X	
Proto X	X	X			X	X	
82	X	X			X	X	
Total	X	X	X		X	X	X

	To Peer				From Peer			
Peers	BPS	PPS	CPS		BPS	PPS	CPS	
1.2.3.4	X	X	X		X	X	X	Details
1.2.3.5	X	X	X		X	X	X	Details
1.2.3.6	X	X	X		X	X	X	Details
1.2.3.7	X	X	X		X	X	X	Details
1.2.3.8	X	X	X		X	X	X	Details
1.2.3.9	X	X	X		X	X	X	Details
1.2.3.10	X	X	X		X	X	X	Details
1.2.3.11	X	X	X		X	X	X	Details
1.2.3.12	X	X	X		X	X	X	Details
1.2.3.13	X	X	X		X	X	X	Details

Clicking on a peer shows the profile for that host.

Clicking on the details link pops up the a->b and b->a stats for the peer.

FIG. 33



Profile for: Employee Desktops Profile Time: Tuesdays - 10:00 AM to 11:59 AM

Tuesdays - 10:00 AM to 11:59 AM
Tuesdays - 8:00 AM to 9:59 AM
Tuesdays - 6:00 AM to 7:59 AM

[illegible]	[illegible]				[illegible]		
	BPS	PPS	CPS		BPS	PPS	CPS
TCP	X	X	X		X	X	X
80 (www)	X	X			X	X	
443 (https)	X	X			X	X	
25 (SMTP)	X	X			X	X	
SYN	X	X			X	X	
FIN	X	X			X	X	
UDP	X	X	X		X	X	X
53 (dns)	X	X			X	X	
ICMP	X	X			X	X	
209	X	X			X	X	
Proto X	X	X			X	X	
82	X	X			X	X	
Total	X	X	X		X	X	X

Intra-role Statistics

	To Peer				From Peer			
Peer	BPS	PPS	CPS		BPS	PPS	CPS	
1.2.3.4	X	X	X		X	X	X	Details
1.2.3.5	X	X	X		X	X	X	Details
1.2.3.6	X	X	X		X	X	X	Details
1.2.3.7	X	X	X		X	X	X	Details

Clicking on a peer host shows the profile for that host.

Clicking on the details link pops up the a->b and b->a stats for the peer.

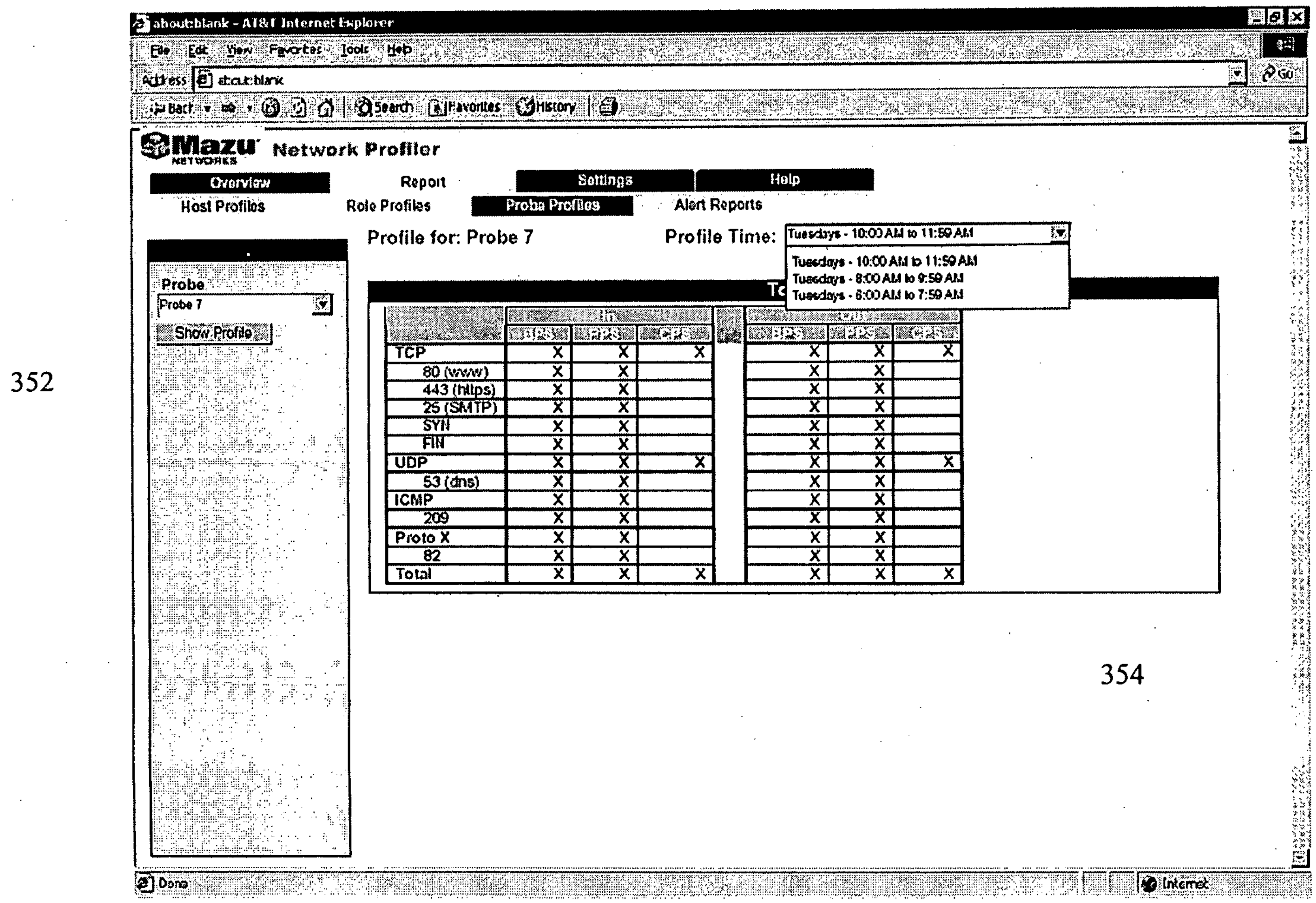
Inter-role Statistics

	To Peer				From Peer			
Peer	BPS	PPS	CPS		BPS	PPS	CPS	
Mail Servers	X	X	X		X	X	X	Details
FTP Servers	X	X	X		X	X	X	Details

Clicking on a peer role shows the profile for that role.

Clicking on the details link pops up the a->b and b->a stats for the peer role.

FIG. 34



Probe: Probe 7

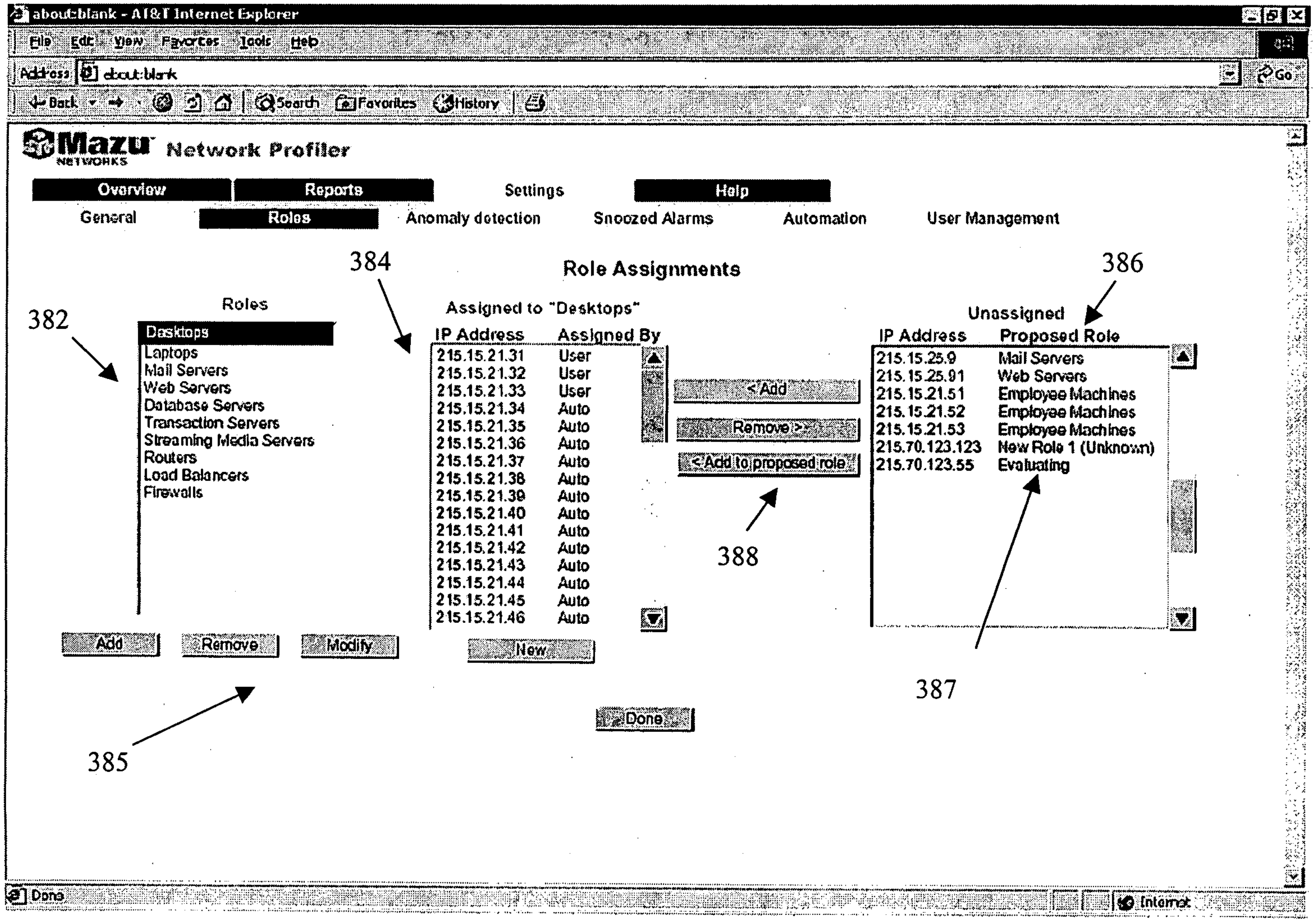
Profile for: Probe 7

Profile Time: Tuesdays - 10:00 AM to 11:59 AM

Tuesdays - 10:00 AM to 11:59 AM
Tuesdays - 8:00 AM to 9:59 AM
Tuesdays - 6:00 AM to 7:59 AM

	In				Out		
	BPS	PPS	CPS		BPS	PPS	CPS
TCP	X	X	X		X	X	X
80 (www)	X	X			X	X	
443 (https)	X	X			X	X	
25 (SMTP)	X	X			X	X	
SYN	X	X			X	X	
FIN	X	X			X	X	
UDP	X	X	X		X	X	X
53 (dns)	X	X			X	X	
ICMP	X	X			X	X	
209	X	X			X	X	
Proto X	X	X			X	X	
82	X	X			X	X	
Total	X	X	X		X	X	X

FIG. 35



Role Assignments

Roles

- Desktops
- Laptops
- Mail Servers
- Web Servers
- Database Servers
- Transaction Servers
- Streaming Media Servers
- Routers
- Load Balancers
- Firewalls

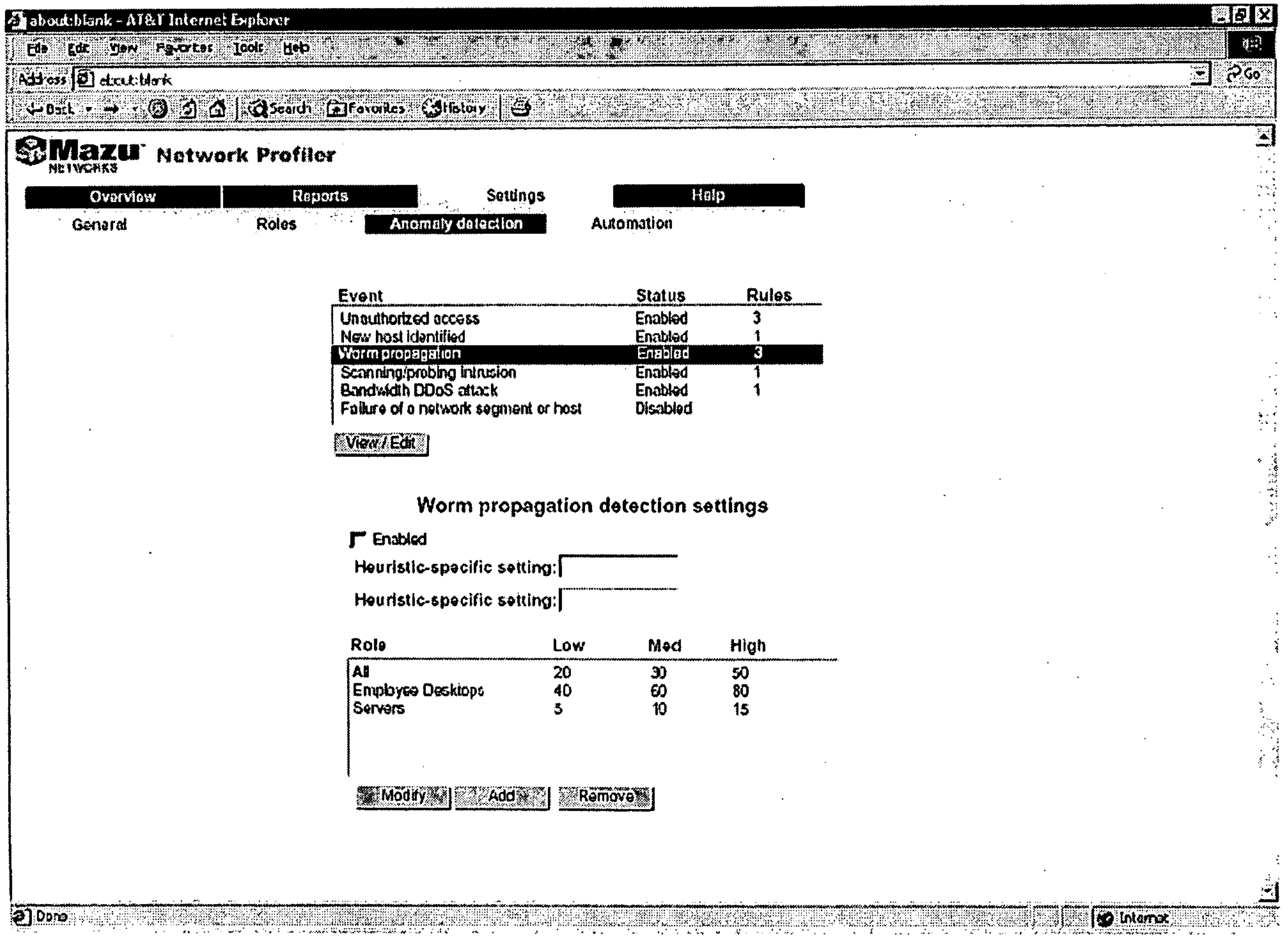
Assigned to "Desktops"

IP Address	Assigned By
215.15.21.31	User
215.15.21.32	User
215.15.21.33	User
215.15.21.34	Auto
215.15.21.35	Auto
215.15.21.36	Auto
215.15.21.37	Auto
215.15.21.38	Auto
215.15.21.39	Auto
215.15.21.40	Auto
215.15.21.41	Auto
215.15.21.42	Auto
215.15.21.43	Auto
215.15.21.44	Auto
215.15.21.45	Auto
215.15.21.46	Auto

Unassigned

IP Address	Proposed Role
215.15.25.9	Mail Servers
215.15.25.91	Web Servers
215.15.21.51	Employee Machines
215.15.21.52	Employee Machines
215.15.21.53	Employee Machines
215.70.123.123	New Role 1 (Unknown)
215.70.123.55	Evaluating

FIG. 36


400
about:blank - AT&T Internet Explorer
File Edit View Favorites Tools Help
Address about:blank
Go
Back Search Favorites History
Mazu NETWORKS Network Profiler
Overview
Reports
Settings
Help
General
Roles
Anomaly detection
Automation
View / Edit
Modify
Add
Remove
Done
Internet

Event	Status	Rules
Unauthorized access	Enabled	3
New host identified	Enabled	1
Worm propagation	Enabled	3
Scanning/probing intrusion	Enabled	1
Bandwidth DDoS attack	Enabled	1
Failure of a network segment or host	Disabled	

Worm propagation detection settings

☑ Enabled

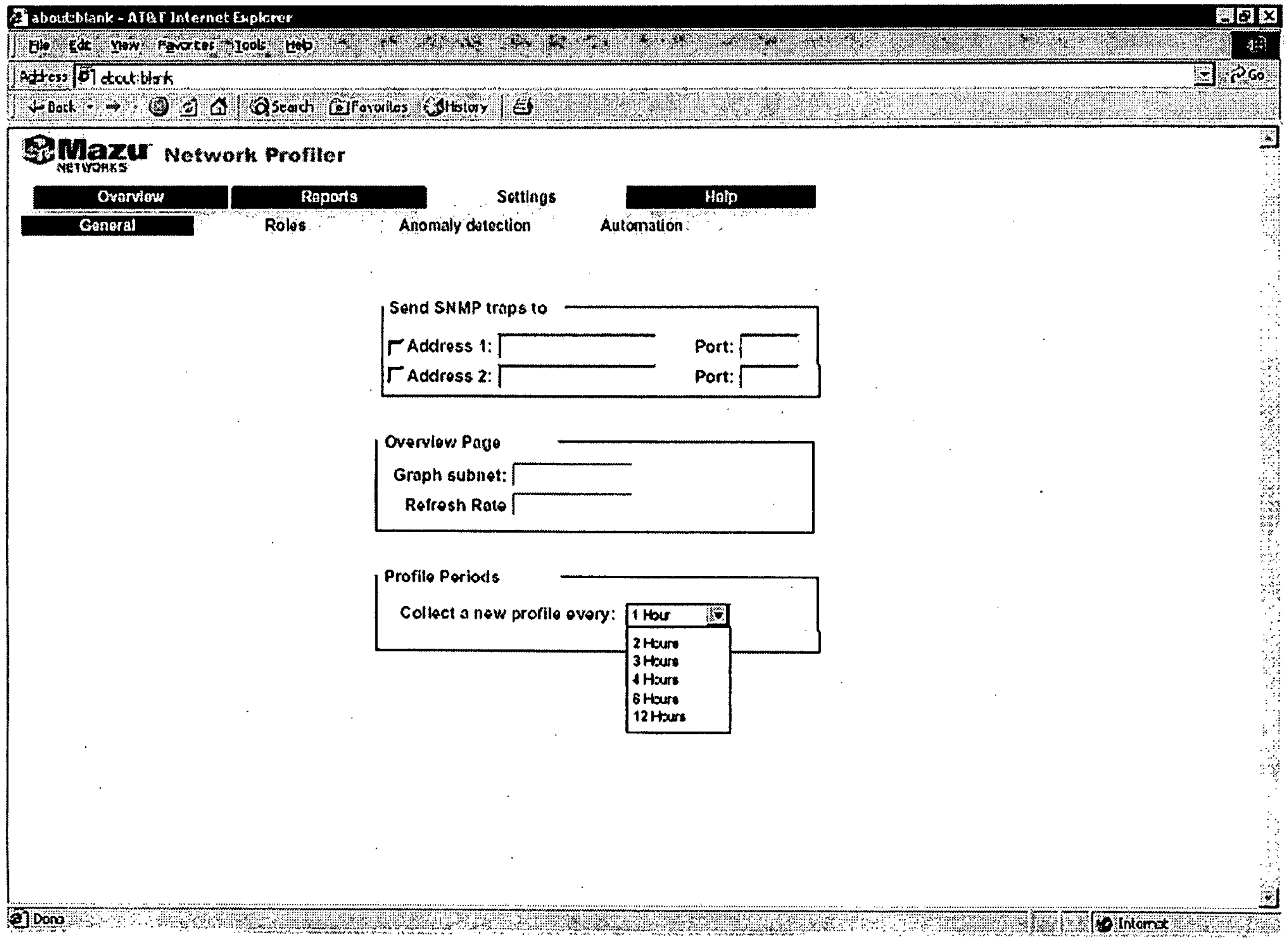
Heuristic-specific setting:

Heuristic-specific setting:

Role	Low	Med	High
All	20	30	50
Employee Desktops	40	60	80
Servers	5	10	15

FIG. 37

410



Send SNMP traps to

☐ Address 1: Port:

☐ Address 2: Port:

Overview Page

Graph subnet:

Refresh Rate

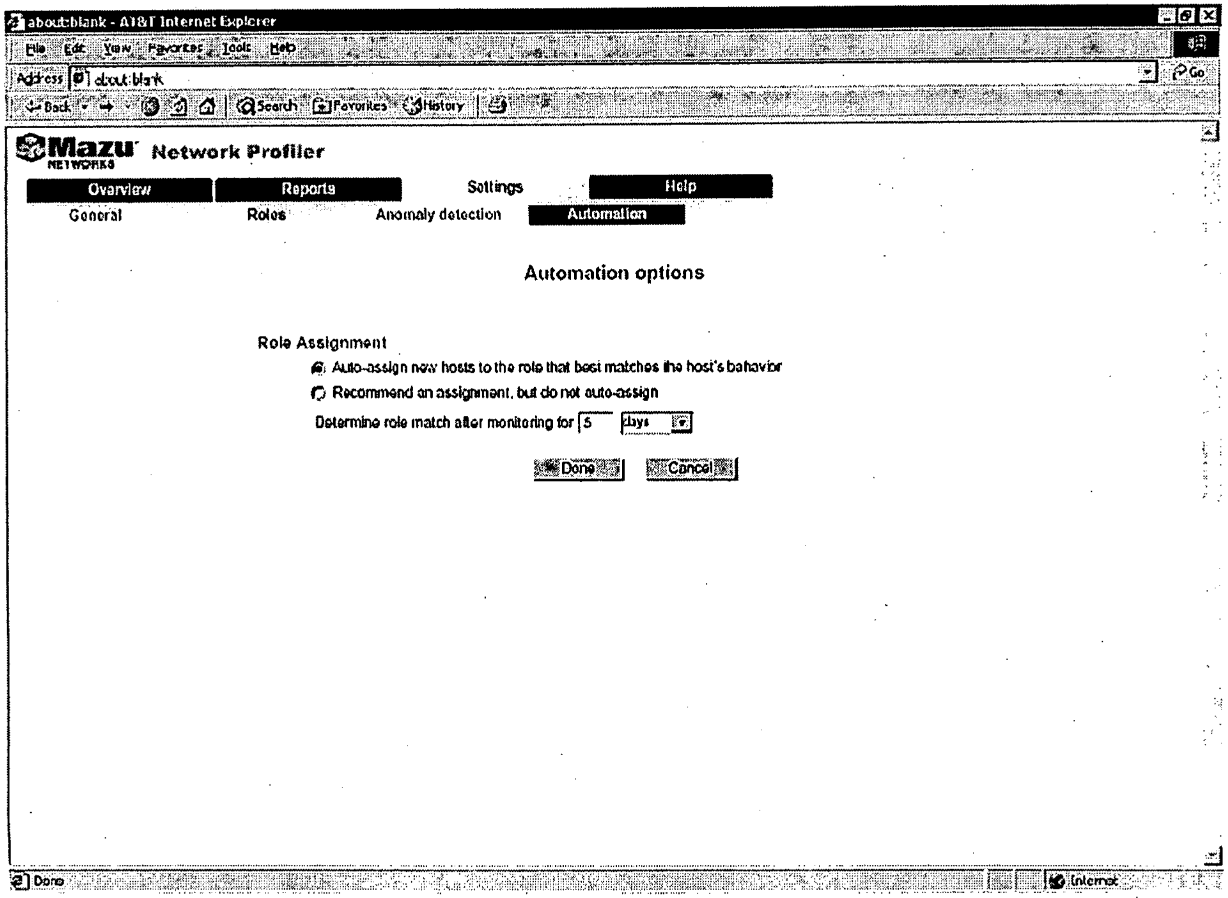
Profile Periods

Collect a new profile every: 1 Hour

2 Hours
3 Hours
4 Hours
6 Hours
12 Hours

FIG. 38

420



Automation options

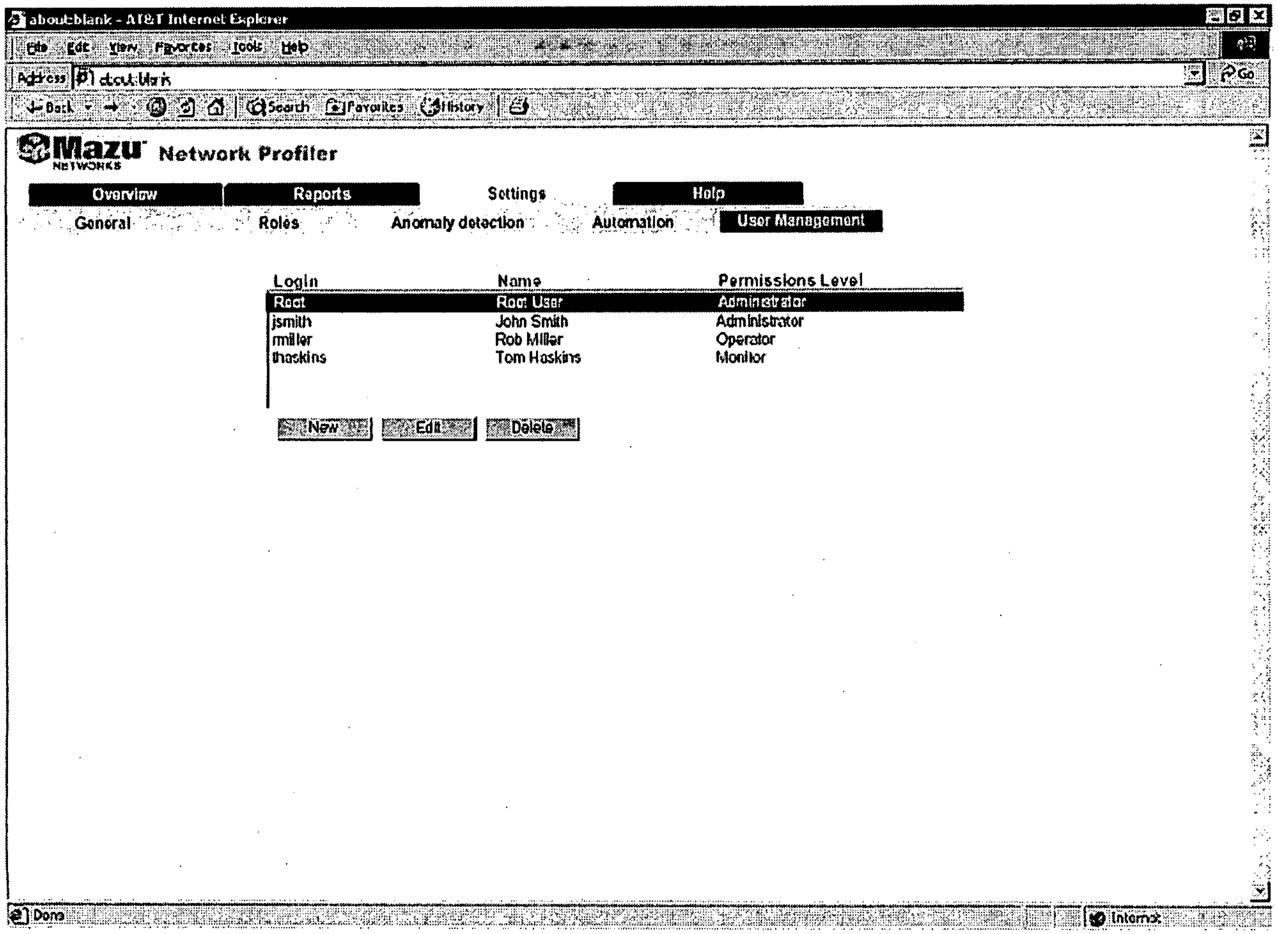
Role Assignment

● Auto-assign new hosts to the role that best matches the host's behavior

○ Recommend an assignment, but do not auto-assign

Determine role match after monitoring for 5 days

FIG. 39


430
about:blank - AT&T Internet Explorer
File Edit View Favorites Tools Help
Address about:blank
Go
Back Search Favorites History
Mazu NETWORKS Network Profiler
Overview
Reports
Settings
Help
General
Roles
Anomaly detection
Automation
User Management
New
Edit
Delete
Done
Internet

Login	Name	Permissions Level
Root	Root User	Administrator
jsmith	John Smith	Administrator
rmiller	Rob Miller	Operator
thaskins	Tom Haskins	Monitor

FIG. 40